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1 Projection Exposure Method and Apparatus

BACKGROUND OF THE INVENTIONField of the Invention

5 The present invention is directed generally to
an exposure method and an exposure apparatus, and more
particularly, to a projection exposure method and a
projection exposure apparatus which are employed in
a lithography process for liquid crystal elements and
10 semiconductor memory cells having regular hyperfine
patterns.

Related Background Art

 A method of transferring mask patterns on a
substrate typically by the photolithography method is
15 adopted in manufacturing semiconductor memories and
liquid crystal elements. In this case, the
illumination light such as ultra-violet rays for
exposure strikes on the substrate having its surface
formed with a photosensitive resist layer through a
20 mask formed with the mask patterns. The mask patterns
are thereby photo-transferred on the substrate.

 The typical hyperfine mask patterns of the
semiconductor memory and the liquid crystal element
can be conceived as regular grating patterns arrayed
25 vertically or horizontally at equal spacings. Formed,
in other words, in the densest pattern region in this
type of mask patterns are the grating patterns in

1 which equally-spaced transparent lines and opaque
lines, formable on the substrate, for attaining the
minimum line width are arrayed alternately in X and/or
Y directions. On the other hand, the patterns having
5 a relatively moderate degree of fineness are formed
in other regions. In any case, the oblique patterns
are exceptional.

Besides, a typical material for the
photosensitive resist exhibits a non-linear
10 photosensitive property. A chemical variation thereof
quickly advances on giving an acceptance quantity
greater than a certain level. If smaller than this
level, however, no chemical variation advances.
Hence, there exists a background wherein if a
15 difference in light quantity between a light portion
and a shade portion is sufficiently secured with
respect to a mask pattern projected image on the
substrate, a desired resist image according to the
mask patterns can be obtained even when a boundary
20 contrast between the light portion and the shade
portion is somewhat low.

In recent years, a projection exposure
apparatus such as a stepper, etc. for transferring the
mask pattern on the substrate by reductive projection
25 has been often employed with a hyperfiner pattern
construction of the semiconductor memory and the
liquid crystal element. Special ultra-violet rays

1 having a shorter wavelength a narrower wavelength
distributing width are employed as illumination light
for exposure. The reason why the wavelength
distribution width is herein narrowed lies in a
5 purpose for eliminating a deterioration in quantity of
the projected image due to a chromatic aberration of
the projection optical system of the projection
exposure apparatus. The reason why the shorter
wavelength is selected lies in a purpose for improving
10 the contrast of the projected image. Shortening of
the wavelength of the illumination light induces a
limit in terms of constraints of lens materials and
resist materials in addition to the fact that no
appropriate light source exists for the much
15 hyperfiner mask patterns required, e.g., for the
projection exposure of line widths on the submicron
order. This is the real situation.

In the hyperfine mask patterns, a required
value of the pattern resolution line width is
20 approximate to the wavelength of the illumination
light. Hence, it is impossible to ignore influences
of diffracted light generated when the illumination
light penetrates the mask patterns. It is also
difficult to secure a sufficient light-and-shade
25 contrast of the mask pattern projected image on the
substrate. In particular, the light-and-shade
contrast at the pattern line edges remarkably

1 declines.

More specifically, respective diffracted light components a 0th-order diffracted light component, (+) primary diffracted light components and those
5 greater than (+) secondary diffracted light components that are generated at respective points on the mask patterns due to the illumination light incident on the mask from above-pass through the projection optical system. These light components are converged again at
10 the respective points on the substrate conjugate these points, thereby forming the image. However, the (+) primary diffracted light components and those larger than the (+) secondary diffracted light components have a much larger diffraction angle than that of the
15 0th-order diffracted light component with respect to the hyperfiner mask patterns and are therefore incident on the substrate at a shallower angle. As a result, a focal depth of the projected image outstandingly decreases. This causes such a problem
20 that a sufficient exposure energy can not be supplied only to some portions corresponding to a part of thickness of the resist layer.

It is therefore required to selectively use the exposure light source having a shorter wavelength
25 or the projection optical system having a larger numerical aperture in order to transfer the hyperfiner patterns. As a matter of course, a strive for

1 optimizing both of the wavelength and the numerical
aperture can be also considered. Proposed in
Japanese Patent Publication No. 62-50811
was a so-called phase shift reticle in which a phase
5 of the transmitted light from a specific portion among
the transmissive portions of reticle circuit patterns
deviates by π from a phase of the transmitted light
from other transmissive portions. When using this
phase shift reticle, the patterns which are hyperfiner
10 than in the prior art are transferable.

In the conventional exposure apparatus,
however, it is presently difficult to provide the
illumination light source with a shorter wavelength
(e.g., 200 nm or under) than the present one for the
15 reason that there exists no appropriate optical
material usable for the transmission optical member.

The numerical aperture of the projection
optical system is already approximate to the
theoretical limit at the present time, and a much
20 larger numerical aperture can not be probably
expected.

Even if the much larger numerical aperture
than at present is attainable, a focal depth expressed
by $\pm \lambda/2NA^2$ is abruptly reduced with an increase of
25 the numerical aperture. There goes conspicuous the
problem that the focal depth needed for an actual use
becomes smaller and smaller. On the other hand, a

1 good number of problems inherent in the phase shift
reticle, wherein the costs increase with more
complicated manufacturing steps thereof, and the
inspecting and modifying methods are not yet
5 established.

Disclosed, on the other hand, in U.S. Patent
No. 4,947,413 granted to T.E. Jewell et al is the
projection lithography method by which a high contrast
pattern projected image is formed with a high
10 resolving power on the substrate by making the 0th-
order diffracted light component coming from the mask
patterns and only one of the (+) and (-) primary
diffracted light components possible of interference
by utilizing a spatial filter processing within the
15 Fourier transform surface in the projection optical
system by use of an off-axis illumination light
source. Based on this method, however, the
illumination light source has to be off-axis-disposed
obliquely to the mask. Besides, the 0th-order
20 diffracted light component is merely interfered with
only one of the (+) and (-) primary diffracted light
components. Therefore, the light-and-shade contrast
of edges of the pattern image is not yet sufficient,
the image being obtained by the interference due to
25 unbalance in terms of a light quantity difference
between the 0th-order diffracted light component and
the primary diffracted light component.

1 SUMMARY OF THE INVENTION

 It is a primary object of the present invention, which has been devised in the light of the foregoing problems, to attain the exposure with a high resolving power and large focal depth even when using
5 an ordinary reticle by making the illumination light incident on a mask at a predetermined angle inclined to the optical axis of an illumination optical axis or a projection optical system, providing a member for
10 making the illumination light incident obliquely on the mask in the illumination optical system and illuminating the mask without any loss in light quantity.

 It is another object of the present invention
15 to provide such an arrangement that passage positions of a 0th-order diffracted light component and (+) primary diffracted light components within a Fourier transfer surface for mask patterns in the projection optical system are set as arbitrary positions
20 symmetric with respect to the optical axis of the projection optical system.

 To accomplish the objects described above, according to one aspect of the present invention, there is provided, in the illumination optical system,
25 a luminous flux distributing member such as a prism, etc. for distributing the illumination light into at least four luminous fluxes penetrating only a

1 predetermined region on the Fourier transform surface
for the mask patterns.

According to another aspect of the present
invention, there is provided a movable optical member
5 such as a movable mirror or the like in the
illumination optical system to concentrate the
luminous fluxes in predetermined positions on the
Fourier transform surface for the mask patterns. The
movable optical member is drivable to cause at least
10 two beams of illumination light to pass through only
the predetermined region on the Fourier transform
surface with time differences from each other.

According to still another aspect of the
present invention, there are provided the luminous
15 flux distributing member or the movable optical member
between an optical integrator such as a fly eye lens,
etc. and the mask or between the light source and the
optical integrator.

According to a further aspect of the present
20 invention, the optical integrator is divided into a
plurality of optical integrator groups which are set
in discrete positions eccentric from the optical axis.
At the same time, the illumination light is focused
on the plurality of optical integrator groups,
25 respectively.

According to still a further aspect of the
present invention, the luminous flux distributing

1 member is movable and exchangeable. The position in
which the luminous flux passes above the Fourier
transform surface for the mask patterns is arbitrarily
set.

5 According to yet another aspect of the present
invention, in a method of effecting the exposure while
deviating a substrate position in the optical-axis
direction of the projection optical system from an
image forming surface of the mask patterns, the
10 exposure is performed by making the illumination light
incident on the mask at an inclined angle.

In accordance with the present invention, it
is possible to actualize a projection type exposure
apparatus exhibiting a higher resolving power and
15 larger focal depth than in the prior art even by
employing the ordinary reticle. Further, although the
effect of improving the resolving power competes with
a phase shifter, the conventional photo mask can be
used as it is. It is also feasible to follow the
20 conventional photo mask inspecting technique as it is.
Besides, when adopting the phase shifter, the effect
of increasing the focal depth is obtained, but it is
hard to undergo influences of a wavefront aberration
due to defocus even in the present invention. For
25 this reason, a large focal depth (focal tolerance) is
obtained.

1 Other objects and advantages of the present invention will become apparent during the following discussion taken in conjunction with the accompanying drawings..

5 BRIEF DESCRIPTION OF THE DRAWINGS

 Fig. 1 is a view schematically illustrating a projection type exposure apparatus in a first embodiment of the present invention;

 Fig. 2 is a view depicting a light
10 transmissive substrate (luminous flux distributing member) including patterns of periodic structure in the first embodiment of the present invention;

 Fig. 3 is a view depicting a spatial filter corresponding to the patterns shown in Fig. 2;

15 Figs. 4 and 6 are views each showing a variant form of the periodic structural patterns in the first embodiment of the present invention;

 Fig. 5 is a view illustrating a spatial filter corresponding to the patterns shown in Fig. 4;

20 Fig. 7 is a view depicting a spatial filter corresponding to the patterns shown in Fig. 6;

 Figs. 8, 9, 10, 11 and 12 are views each showing a variant form of the luminous flux distributing member in the first embodiment;

25 Fig. 13 is a view of a drive unit for the luminous flux distributing member of Fig. 12;

 Fig. 14 is a view schematically showing a

1 light path from the Fourier transform surface for the
reticle to the projection optical system in the
projection type exposure apparatus according to the
first embodiment of the present invention;

5 Figs. 15A and 15C are plan views showing one
example of the reticle patterns formed on the mask;

Figs. 15B and 15D are views of assistance in
explaining the placement of respective exit portions
(surface illuminant image) on the Fourier transform
10 surface for the reticle patterns corresponding to
Figs. 15A and 15C, respectively;

Fig. 16 is a view schematically illustrating
a projection type exposure apparatus in a second
embodiment of the present invention;

15 Figs. 17 and 18 are views showing a variant
form of the movable optical member according to the
present invention;

Figs. 19A and 19B are flowcharts showing an
exposure method in the second embodiment of the
20 present invention;

Fig. 20 is a view schematically illustrating
a projection type exposure apparatus in a third
embodiment of the present invention;

Figs. 21, 22, 23, 24 and 25 are views each
25 showing a part of an input optical system;

Fig. 26 is a view showing an illumination
system when incorporating a reticle blind into the

1 exposure apparatus of Fig. 20;

Fig. 27 is a view depicting a configuration
about a wafer stage of the projection type exposure
apparatus in the third embodiment of the present
5 invention;

Figs. 28A and 28B are graphic charts each
showing velocity characteristics of a Z-stage and
abundance probabilities of the exposure quantity when
executing a cumulative focal point exposure method by
10 use of the Z-stage of the wafer stage;

Fig. 29 is a view schematically illustrating
a projection type exposure apparatus in a fourth
embodiment of the present invention;

Figs. 30, 31, 32, 33 and 34 are views showing
15 variant forms of the input optical system;

Fig. 35 is a plan view taken substantially in
the optical-axis direction, showing a placement of
movable fly eye lens groups and a construction of a
movable member thereof;

20 Fig. 36 is a view taken substantially in the
direction vertical to the optical axis, showing the
construction of Fig. 35;

Fig. 37 is a view schematically illustrating
a projection type exposure apparatus in a fifth
25 embodiment of the present invention;

Fig. 38 is a view depicting a concrete
construction of the movable member (switching member

1 of this invention) for exchanging four pieces of
holding members consisting of a plurality of fly eye
lens groups;

Fig. 39 is a view showing a variant form
5 of the movable member for exchanging the plurality
of holding member; and

Fig. 40 is a view schematically showing a
fundamental construction of a light path in the first
embodiment of the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will
hereinafter be described in detail with reference to
the accompanying drawings. Fig. 1 is a block diagram
15 illustrating a whole projection type exposure
apparatus in accordance with a first embodiment of the
present invention. A luminous flux L1 emitted from an
exposure light source 1 such a mercury lamp or the
like and converged by an elliptical mirror 2 is
20 reflected by a mirror 3. The luminous flux reflected
by the mirror 3 passes through a relay lens 4 and is
monochromatized by a wavelength selection element 5.
A monochromatized luminous flux L2 is refracted by a
mirror 6 and is incident on a fly eye lens 7. At this
25 moment, an incident surface of the fly eye lens 7 is
provided in a position substantially conjugate to
reticle patterns 28. An exit surface of the fly eye

1 lens 7 is formed on a Fourier transform corresponding
surface (Fourier transform surface) of the reticle
patterns 28 or in the vicinity of this surface. An
aperture stop 8 is provided in close proximity to the
5 exit surface of the fly eye lens 7. A numerical
aperture of illumination light L3 is determined by a
drive unit 9 for making variable a size of an opening
of the aperture stop 8. The illumination light L3 is
reflected by a mirror 10. Illuminated with the
10 illumination light through a condenser lens 11 is a
diffraction grating pattern plate (light transmissive
flat plate) 12 incised with diffraction grating
patterns 13a. This diffraction grating pattern plate
12 functions as a luminous flux distribution member in
15 the present invention. This plate 12 is
attachable/detachable and interchangeable. At this
time, the diffraction rating pattern plate 12 is
provided on a surface substantially conjugate to
the hyperfine reticle pattern surfaces 28 formed on a
20 reticle 7. The reticle patterns 28 may be herein
isolated patterns or patterns having a periodic
structure.

As described above, an optical integrator such
as the fly eye lens and fibers is used in an
25 illumination optical system for illuminating the
reticle with the light. Uniformed is an intensity
distribution of the illumination light with which the

1 reticle is illuminated. In the case of employing the
fly eye lens to optically effect this homogenizing
process, a reticle side focal surface and a reticle
surface are linked based substantially on a relation
5 of Fourier transform. The reticle side focal surface
and a light source side focal surface are also linked
based the relation of Fourier transform. Hence, the
pattern surface of the reticle and the light source
side focal surface (precisely the light source side
10 focal surface of each individual lens element of the
fly eye lens) are linked based on an image forming
relation (conjugate relation). For this reason, on
the reticle, the illumination beams from the
respective elements (secondary illuminant image) of
15 the fly eye lens are added (overlapped) and thereby
averaged. An illuminance homogeneity
on the reticle can be thus enhanced.

Fig. 2 is a plan view showing one example of
the diffraction grating pattern plate.

20 The diffraction grating pattern plate 12 is
a transparent substrate of fused quartz or the like
and is formed with the diffraction grating pattern
13a. The diffraction grating patterns 13a are
conceived as line-and-space patterns formed of a flare
25 metal thin film of Cr and the like. Note that at this
time, a pitch P_g of the diffraction grating patterns
13a are desirably substantially given by $P_g = 2P_r \times M$

1 (m is the magnification of image formation between
the diffraction grating pattern 13a and the reticle
patterns 28) with respect to a pitch P_r of the reticle
patterns 28. A duty thereof is not necessarily 1 : 1
5 but may be arbitrary.

Now, returning to the description of Fig. 1,
(-) primary diffracted light L4 and (+) primary
diffracted light L5 generated by the diffraction
grating pattern plate 12 are separated from each other
10 by a condenser lens 15 on a Fourier transform surface
50 in the illumination optical system. The beams of
light are then condensed in a position eccentric from
the optical axis of the illumination optical system
(or a projection optical system (29)). The positions
15 through which the beams of (+) primary diffracted
light L4, L5 pass above the Fourier transform surface
are symmetric with respect to an optical axis AX. A
spatial filter 16 is provided on the Fourier transform
surface or on a surface in the vicinity of the Fourier
20 transform surface. Light transmissive positions
(openings) are provided in such positions as to
transmit only the beams of diffracted light ((+) primary
diffracted light L4, L5 in this embodiment) of
the specific order among the beams of diffracted light
25 generated from the diffraction grating patterns 13a.
Note that this spatial filter 16 may be such a
variable type filter as to make variable a position

1 and a configuration of the transmissive portion or may
be a filter of such a type that the spatial filter 16
itself is attachable/detachable and interchangeable.
The spatial filter 16 is preferably provided with,
5 when the 0th-order diffracted light is generated from
the diffraction grating pattern 13a, a Cr thin film
having a size enough to shield the 0th-order
diffracted light. Beams of light of unnecessary
orders can be also shielded.

10 Fig. 3 depicts a spatial filter 16a suitable
when using the diffraction grating patterns 13a shown
in Fig. 2. An oblique line portion indicates a light
shielding portion. A radius of the spatial filter 16a
is set greater than a total numerical aperture of the
15 illumination optical system. Two light transmissive
portions (openings) 16a1, 16a2 are provided in
portions symmetric with respect to the central point
of the spatial filter 16a.

An intensity distribution (positions of
20 luminous fluxes) on the Fourier transform surface of
the illumination optical system required differs
depending on the directivity of the reticle pattern
28. It is, however, desirable that the directivity of
the diffraction grating patterns 13a be equal to the
25 directivity of the reticle patterns 28. In this case,
it is not necessary that the directivities be
identical. The directivity of the diffraction grating

1 patterns 13a projected on the reticle pattern 28 may
be coincident with a large proportion of the
directivity of the reticle patterns 28. To implement
these requirements, intrinsic diffraction grating
5 patterns determined for the respective reticle
patterns 28 are incised in individual diffraction
rating pattern plates. Simultaneously when replacing
a reticle 27, the reticle 27 may be replaced while
matching it with the diffraction grating pattern
10 plate.

The diffraction grating patterns 13a are
determined by the pitch or line width and the
directivity of the reticle patterns 28. Hence, the
same diffraction grating patterns plate may be used
15 in common to a plurality of reticles having patterns
in which the pitches, line widths and the
directivities are substantially equal.

If the directivities of the plurality of
reticles are different, they may be made coincident
20 with the directivities of the patterns on the
respective reticles by rotating the diffraction
grating pattern plate 12 within a plate vertical to
the optical axis. Further, if the diffraction grating
pattern plate 12 is rotatable (through, e.g., 90°),
25 a correspondence can be given to such a case that
the line-and-space pattern directions of the reticle
patterns 13a are different from directions x, y.

1 The relay lens 15 is set as a zoom lens (afocal zoom
expander and the like) composed of a plurality of lens
elements, wherein a condensing distance is variable by
changing a focal distance. In this case, however,
5 the conjugate relation between the diffraction
grating pattern plate 12 and the reticle 27 should
be kept. Further, an image of the pattern 13a may be
rotated by use of an image rotator.

For instance, the diffraction grating patterns
10 13a may be employed in a state of being rotated about
the optical axis of the illumination optical system
to obtain an arbitrary angle in accordance with the
directivity of the reticle patterns 28.

Now, as illustrated in Fig. 1, the luminous
15 fluxes L4, L5 passing through the spatial filter 16
are led to a reticle blind 20 via a condenser lens
19. The reticle blind 20 is provided on a surface
substantially conjugate to the reticle pattern
surfaces 28 and is a field stop for illuminating only
20 the specific area on the reticle 27 with the light.
This reticle blind 20 has an aperture openable and
closable, with the aid of a drive system 21 and is
capable of adjusting a size of the illumination area
on the reticle 27. The reticle 27 is illuminated
25 with luminous fluxes L6, L7 passing through the
reticle blind 20 through condenser lenses 22, 26 and a
mirror 24 disposed substantially in the vicinity of

1 the Fourier transform surface. The luminous fluxes
L6, L7 are incident on the reticle patterns 28. The
beams of diffracted light generated from the reticle
patterns 28 are condensed to form an image on a wafer
5 30 by means of a projection optical system 29. The
wafer 30 is two-dimensionally movable within the plane
vertical to the optical axis. The wafer 30 is placed
on a wafer stage 31 movable in the optical-axis
direction.

10 Fig. 40 schematically illustrates a
fundamental configuration of light paths for
illumination beams in an exposure apparatus in this
embodiment. Referring to Fig. 40, the light
transmissive portion (opening) 16a of the spatial
15 filter 16 is disposed in a position eccentric from
the optical axis AX of the projection optical system
or the illumination optical system on the Fourier
transform surface. A coordinate position of the
luminous fluxes passing through the Fourier transform
20 surface is eccentric from the optical axis AX.

Now, the illumination light L5 emitted from
the exit portion 16a of the spatial filter 16 is
incident on the reticle 27 via the condenser lens 26.
The reticle patterns 28 depicted on the reticle (mask)
25 27 typically contain a large number of periodic
patterns. Therefore, a 0th-order diffracted light
component D0, (+) primary diffracted light components

1 Dp, Dm and higher-order diffracted light components
are generated in directions corresponding to degrees
of fineness of the patterns from the reticle patterns
28 illuminated with the light. At this moment, the
5 illumination luminous fluxes (central line) are
incident on the reticle 27 at an inclined angle.
Hence, the diffracted light component of the
respective orders are also generated from the reticle
patterns 28 with an inclination (angular deviation) as
10 compared with the vertical illumination. The
illumination light L6 shown in Fig. 40 is incident
on the reticle 27 with an inclination ϕ to the optical
axis.

The illumination light L6 is diffracted by
15 the reticle patterns 28, thereby generating a 0th-
order diffracted light component Do traveling in a
direction with the inclination ϕ to the optical axis
AX, a (+) primary diffracted light component Dp with
an inclination θ_p to the 0th-order diffracted light
20 component and a (-) primary diffracted light component
Dm traveling with an inclination θ_m to the 0th-order
diffracted light component Do. The illumination light
L6 is, however, incident on the reticle patterns at
the inclined angle ϕ to the optical axis AX of the
25 projection optical system 29 both sides of which are
telecentric. For this reason, the 0th-order
diffracted light component Do also travels in the

1 direction inclined at the angle φ to the optical axis
AX of the projection optical system.

Hence, the (+) primary diffracted light
component D_p travels in a direction of $(\theta_p + \varphi)$ to
5 the optical axis AX, while the (-) primary diffracted
light component D_m goes in a direction of $(\theta_m - \varphi)$
to the optical axis AX.

At this time, the diffracted angles θ_p , θ_m
are expressed such as:

10 $\sin (\theta_p + \varphi) - \sin \varphi = \lambda / P \quad \dots (1)$

$$\sin (\theta_m - \varphi) + \sin \varphi = \lambda / P \quad \dots (2)$$

where it is assumed that both of the (+) primary
diffracted light component D_p and (-) primary
diffracted light component D_m penetrate a pupil
15 surface (the Fourier transform surface of the reticle
patterns) 51 of the projection optical system 29.

When the diffracted angle increases with
finer reticle patterns 28, the (+) primary diffracted
light component D_p traveling in the direction inclined
20 at the angle of $(\theta_p + \varphi)$ at first becomes incapable
of penetrating the pupil surface 51 of the projection
optical system 29. Namely, there is developed a
relation such as $\sin (\theta_p + \varphi) > NA_R$. A beam of
illumination light L131 is incident with an
25 inclination to the optical axis AX, and hence the
(-) primary diffracted light component D_m is capable
of incidence on the projection optical system 29 even

1 at the diffracted angle of this time. Namely, there
is developed a relation such as $\sin (\theta_m - \varphi) < NA_R$.

Produced consequently on the wafer 30 are
interference fringes by two luminous fluxes of the
5 0th-order diffracted light component D_0 and the (-)
primary diffracted light component D_m . The
interference fringes are conceived as an image of the
reticle patterns 28. A contrast of approximately
90 % is obtained when the reticle patterns 28 have a
10 line-and-space of 1 : 1, and patterning of the image
of the reticle patterns 28 can be effected on a resist
applied over the wafer 30.

A resolving limit at this moment is given by:

$$\sin (\theta_m - \varphi) = NA_R \quad \dots (3)$$

15 Hence, a reticle-side pitch of the transferable
minimum pattern is given by:

$$\begin{aligned} NA_R + \sin \varphi &= \lambda / P \\ P &= \lambda / (NA_R + \sin \varphi) \quad \dots (4) \end{aligned}$$

Now, supposing that $\sin \varphi$ is set to
20 approximately $0.5 \times NA_R$ as one example, the minimum
pitch of the pattern on the transferable reticle is
given by:

$$\begin{aligned} P &= \lambda / (NA_R + 0.5NA_R) \\ &= 2\lambda / 3NA_R \quad \dots (5) \end{aligned}$$

25 On the other hand, in the case of a known
projection exposure apparatus in which a distribution
of illumination light on the pupil surface 51 of the

1 Fourier transform surface falls within a circular
range (rectangular range) about the optical axis AX,
the resolving limit is expressed by $\sin \theta_m = \lambda/p \simeq$
NA_R. The minimum pitch is given by $P \simeq \lambda/NA_R$. It
5 can be therefore understood that the projection type
exposure apparatus in this embodiment attains a higher
resolving power than in the known exposure apparatus.

The following is an elucidation about why
a focal depth becomes large on the basis of a method
10 of forming image forming patterns on the wafer by use
of the 0th-order diffracted light component and the
primary diffracted light component while the reticle
patterns are irradiated with the exposure light in
a specific incident direction at a specific incident
15 angle.

As illustrated in Fig. 40, when the wafer 30
is coincident with the focal position (the best image
forming surface) of the projection optical system 29,
all the individual diffracted light components
20 emerging from one point of the reticle patterns 28
and reaching one point on the wafer 30, even if they
pass through any part of the projection optical system
29, have an equal length of light path. For this
reason, even when the 0th-order diffracted light
25 component penetrates substantially the center (in the
vicinity of the optical axis) of the pupil surface 51
of the projection optical system 29, the 0th-order

1 diffracted light component and other diffracted light
components are equal in terms of lengths of their
light paths, and a mutual wavefront aberration is
zero. When the wafer 30 is in a defocus state (the
5 wafer 30 does not coincide with the focal position of
the projection optical system 29), however, the
lengths of the high-order diffracted light components
obliquely falling thereon are short in front of the
focal point as compared with the 0th-order diffracted
10 light component passing in the 0th-order diffracted,
light component passing in the vicinity of the optical
axis. Whereas in rear of the focal point (closer
to the projection optical system 29), the lengths
increases. A difference therebetween corresponds to a
15 difference between the incident angles. Hence, the
0th-order, primary, ... diffracted light components
mutually form the wavefront aberration, resulting in
creation of unsharpness in front and in rear of the
position of the focal point.

20 The wavefront aberration caused by the defocus
described above is defined as a quantity given by
 $\Delta F r^2 / 2$, where ΔF is the amount of deviation from the
focal point position of the wafer 30, and r ($r =$
 $\sin \theta_w$) is the sine of an incident angle θ_w in the
25 case of (-) incidence of the individual diffracted
light component. (At this time, r represents a
distance from the optical axis AX on the pupil surface

1 51.) In the conventional known projection type
exposure apparatus, the 0th-order diffracted light
component D_0 passes in the vicinity of the optical
axis AX, and hence r (0th-order) = 0. On the other
5 hand, in the (+) primary diffracted light components
 D_p , D_m , r (primary) = $M \cdot \lambda / P$ (M is the magnification
of the projection optical system).

Therefore, the wavefront aberration due to
defocusing of the 0th-order diffracted light component
10 D_0 and the (+) primary diffracted light components D_p ,
 D_m is given by:

$$\Delta F \cdot M^2 (\lambda / P)^2 / 2$$

On the other hand, in the projection type
exposure apparatus according to this invention, as
15 illustrated in Fig. 40, the 0th-order diffracted
light component D_0 is generated in the direction
inclined at the angle ϕ to the optical axis AX. Thus,
the distance of the 0th-order diffracted light
component from the optical axis AX on the pupil
20 surface 51 is expressed such as r (0th-order) = $M \cdot$
 $\sin \phi$.

Further, the distance of the (-) primary
diffracted light component D_m from the optical axis on
the pupil surface is expressed such as r ((-) primary)
25 = $M \cdot \sin \phi (\theta_m - \phi)$. At this time, if $\sin \phi = \sin (\theta_m -$
 $\phi)$, a relative wavefront aberration due to defocusing
of the 0th-order diffracted light component D_0 and the

1 (-) primary diffracted light component D_m becomes
zero. Even when the wafer 30 deviates slightly in the
optical-axis direction from the position of the focal
point, it follows that the unsharp image of the
5 patterns 28 does not become larger than in the prior
arts. Namely, the focal depth increases. As shown
in the formula (2), $\sin(\theta_m - \phi) + \sin\phi = \lambda/P$, and
hence it is possible to remarkably increase the focal
depth on condition that the incident angle ϕ of the
10 illumination luminous flux L_6 to the reticle 27 is
made to have a relation such as $\sin\phi = \lambda/2P$ with
respect to the patterns having the pitch P .

Herein, as discussed above, each of the
luminous fluxes L_6 , L_7 is incident on the reticle 28
15 at the inclined angle ϕ in symmetry with respect to
the optical axis of the projection optical system or
the illumination optical system. Generated from the
patterns 28 are the 0th-order diffracted light
component D_0 , a (-) primary light component D_m and
20 a (+) primary light component D_p .

The incident angle ϕ is prescribed by a
numerical aperture NA of the projection optical system
as well as by the reticle patterns 28. As expressed
in the formula (4), this incident angle is selectively
25 set to an incident angle corresponding to the minimum
value of the reticle pattern pitch. The incident
direction is desirably set to a pitch array direction

1 of the reticle patterns. The optimum conditions of
the incident angle will be explained later.

Herein, as described above, the diffraction
grating pattern plate 12 is disposed in the position
5 substantially conjugate to the reticle patterns 28.
The diffraction grating patterns 13a are therefore
projected on the reticle patterns 28 via the
illumination optical system. For this reason, a
light-and-shade image assuming the diffraction grating
10 configuration is formed on the reticle patterns 28,
and the uniformity in amount of illumination light
is thereby deteriorated. However, the diffraction
grating pattern plate 12 incised with the diffraction
grating patterns 13a is oscillated or shifted by one
15 pitch of the diffraction grating patterns 13a or by
approximately an integer multiple or greater during an
expousre period (while an unillustrated shutter is
opened) per shot by a drive member 14 such as a motor,
a piezoelement and the like. The light-and-shade
20 image is thereby shifted by approximately one pitch or
larger during the exposure period per shot. The
luminance is averaged (homogenized) in terms of time,
thereby keeping well the uniformity in quantity of
the illumination light. The direction in which the
25 light-and-shade image is shifted or oscillated is
preferably set to exhibit a less correlation with the
direction of the diffraction grating patterns 13a.

1 For instance, the image is allowed to make a circular
motion (synthesized with the oscillations in the
directions x and y) wherein a diameter is set to a
value which exceeds the pitch P_g of the patterns 13a
5 within the plane vertical to the optical axis.

At this time, one or more optical members
closer to the reticle 27 than the diffraction grating
pattern plate 12 may be shifted, oscillated or allowed
to make the circular motion under the same conditions
10 within the illumination optical system in place of the
diffraction grating pattern plate 12. Fig. 1 shows an
example where drive members 23, 25 are attached to
the condenser lens 22 and the mirror 24.

The light-and-shade image is averaged within
15 the exposure period by giving the above-described
shifting, oscillating or circular motion. The
illumination light quantity on the reticle patterns
28 can be kept uniform.

There is, however, a possibility to cause
20 unevenness in the light quantity on the reticle
pattern surfaces 28 due to a dispersion in diffraction
efficiency or in transmissivity within the pattern
plane which is derived from a manufacturing error of
the diffraction grating patterns 13a. To prevent this
25 phenomenon, a light scattering member 17 such as a
diffusion plate of a lemon skin and the like may be
disposed in close proximity to the Fourier transform

1 surface 50.

The light emerging from one point on the diffraction grating patterns 13a is scattered by the light scattering member 17 and serves for illumination
5 over a wide area of the reticle pattern surfaces 28. In other words, the light from the wide area of the diffraction grating patterns 13a reaches one point on the reticle pattern surfaces 28. A local error in manufacture of the diffraction grating patterns 13a
10 is relieved. At this time, the light scattering member 17 is shifted, oscillated or rotated by a motor 18 during the exposure period per shot, whereby a time averaging effect is produced. This makes it easier to eliminate the dispersion in the quantity
15 of the illumination light.

Note that when shifting, oscillating or rotating the light scattering member 17, the optical members such as the diffraction grating pattern plate 12 or the condenser lens 22 and the mirror 24 may not be
20 shifted, oscillated or rotated.

This light scattering member 17 provided in the vicinity of the Fourier transform surface deteriorates the image of the diffraction grating patterns 13a but does not cause extreme fluctuations
25 in the angular range of the incident angles of the illumination light incident on the reticle pattern surface 28.

1 In addition, the fiber bundles may be laid
leastwise larger than the spot beams on the Fourier
transform surface or over the entire Fourier transform
surface in place of the light scattering member 17 to
5 deteriorate the light fluxes. Further, the effect
to deteriorate the image can be enhanced by a
combination with the light scattering member 17.

 Incidentally, the device depicted in Fig. 1
includes: a main control system 58 for
10 generalizing/controlling the device; a bar code reader
61 for reading bar codes BC representing the names
prepared a side of the reticle patterns 28 in the
course of carrying the reticle 27 just above the
projection optical system 29; and a keyboard 62 for
15 inputting commands and data from the operator.
Registered beforehand in the main control system 58
are the names of a plurality of reticles dealt with by
this stepper and stepper operation parameters
corresponding to the respective names. The main
20 controller system 58 outputs, when the bar code reader
61 reads the reticle bar code BC, the previously
registered information on the shift and the rotation
of the diffraction grating pattern plate 12 to the
drive member 14 as one of the operaiton parameters
25 which corresponds to that name. The optimum
distribution of the light quantity can be thereby
formed on the Fourier transform surface 50 in

1 accordance with the reticle patterns on the reticle.
As one of the parameters corresponding to the names of
the reticles, the information on the replacement of
the diffraction grating pattern plate 12 is inputted
5 to a reticle replacing member 62. The diffraction
grating pattern plate 12 optimal to the reticle
patterns 28 formed on the reticle is thereby
selectable. The operations discussed above are
executable by the operator's inputting the commands
10 and data directly to the main control system 58 from
the keyboard 63.

Now, in order to intensify the effect of
improving the resolving power in this embodiment,
preferably $\sigma = 0.1$ to 0.3 by adjusting the numerical
15 aperture 8 of the illumination system. The reason
for this is that the improvements of the resolving
power and of the focal depth are not attainable if
the value σ is too large, and whereas if too small, a
fidelity declines. Hence, when an exit area of the
20 fly eye lens 7 of the above-described illumination
optical system is set to 1, it is desirable to
manufacture a fly eye lens having an exit area of,
e.g. 0.3 in contrast with that value. The
illumination optical system from the elliptical mirror
25 2 to the fly eye lens 7 may preferably be constructed
to maximize the light quantity with respect to $\sigma \approx$
 0.3 . In addition, the value σ may be variable by

1 changing the width of luminous fluxes incident on the
fly eye lens 7 with the lens system 4 being composed
of a zoom lens (afocal zoom lens).

The foregoing positions of the respective
5 mirror are not limited to the above-mentioned. For
instance, the mirror 24 fitted with the drive member
25 may be disposed closer to the spatial filter 16
than the reticle blind 20.

Next, there will be explained a case where
10 the reticle patterns 28 are not oriented uniformly
over the entire surface of the reticle but oriented
partially in different directions.

For example, a case where the reticle patterns
28 have the periodic structure in two directions x, y
15 will be described. Where the reticle patterns 28 have
the periodic structure in the two directions x, y,
there may be employed the diffraction grating pattern
plate 12 formed with diffraction grating patterns 13b
arrayed partially in different directions as shown in
20 Fig. 4. Referring to Fig. 4, diffraction grating
patterns 13b1, 13b3 correspond to the reticle patterns
28 having the periodic structure in the direction y.
Diffraction grating patterns 13b2, 13b3 correspond to
the reticle patterns 28 having the periodic structure
25 in the direction x. At this time, the pitch array
direction of the diffraction grating patterns 13b1,
13b3 is equalized to the pitch array direction of the

1 reticle patterns 28 having the periodic structure
in the direction y. The pitch array direction of the
diffraction grating patterns 13b2, 13b3 is equalized
to the pitch array direction of the reticle patterns
5 28 having the periodic structure in the direction y.

Fig. 5 is a diagram illustrating a spatial
filter 16b corresponding to the diffraction grating
pattern 13b depicted in Fig. 4. The spatial filter
16b includes light transmissive portions (openings)
10 160a, 160b, 160c, 160d. The oblique line portion
indicates a light shielding portion. The light
transmissive portions 160a, 160c transmit the
diffracted light generated from the diffraction
grating patterns 13b1, 13b3. A spacing between the
15 light transmissive portions 160a, 160b is determined
by a pitch of the diffraction grating patterns 13b1,
13b3. A direction and an angle of the diffracted
light incident on the reticle patterns are determined
by positions of the beams of refracted light at the
20 spatial filter 16, i.e., by positions of the light
transmissive portions 160a, 160c.

Similarly, the light transmissive portions
160b, 160d transmit the diffracted light from the
diffraction grating patterns 13b2, 13b4. A direction
25 and an angle of the luminous flux incident on the
reticle patterns 28 are determined by the position
of the refracted light on the spatial filter 16 which

1 is conditional to the pitch of the diffraction grating
patterns 13b2, 13b4.

A configuration of the diffraction grating
pattern 13b is not limited to the line-and-space
5 depicted in Fig. 4 but may be a checked grating
pattern 13c illustrated in Fig. 6. The pitch array
direction is desirably matched with the array
direction of the reticle patterns 28. As discussed
above, if the periodic patterns on the reticle are
10 arrayed in the two directions x, y, as illustrated
in Fig. 6, the pitches of the checked grating pattern
13c may be set in the directions x, y. A duty
thereof is not limited to 1 : 1.

Fig. 7 illustrates a spatial filter 16c for
15 the checked grating pattern 13c shown in Fig. 6. The
spatial filter 16c includes light transmissive
portions 161a, 161b, 161c, 161d. The oblique line
portion indicates the light shielded portion.

Spacings between the light transmissive
20 portions 161a, 161b and 161d, 161c are determined
by the x-directional pitch of the diffraction grating
pattern 13c shown in Fig. 6. Spacings between the
light transmissive portions 161a, 161d and 161b, 161c
are determined by the y-directional pitch of the
25 diffraction grating pattern 13c shown in Fig. 6.
Where the reticle patterns 28 have the periodic
structure in the two directions x, y, the illumination

1 light penetrating the light transmissive portions
161a, 161d is incident on the reticle patterns 28
having the x-directional periodic structure, thereby
generating the (+) primary diffracted light component.
5 This diffracted light component passes through
substantially the same position as that of the 0th-
order diffracted light component of the illumination
light which has penetrated the light transmissive
portions 161b, 161c respectively on the pupil surface
10 51 of the projection optical system 29. Reversely,
the illumination light penetrating the light
transmissive portions 161b, 161c is incident on the
reticle patterns 28 having the x-directional periodic
structure, thereby generating the (-) primary
15 diffracted light component. This diffracted light
component passes through substantially the same
position as that of the illumination light which has
penetrated the light transmissive portions 161a, 161d
respectively on the pupil surface 51 of the projection
20 optical system. Distances from the optical axis to
the respective light transmissive portions 161a, 161b,
161c, 161d are equally set. Therefore, the 0th-order
diffracted light component and the (+) primary
diffracted light component or the (-) primary
25 diffracted light component pass through the positions
having substantially equal distances from the optical
axis on the pupil surface of the projection optical

1 system. Four beams of illumination light passing
through the light transmissive portions 161a to 161d
are incident on the reticle patterns 28, thereby
generating (+) or (-) primary diffracted light
5 component. Combined light components of any one of
these primary diffracted light components and the 0th-
order diffracted light component all reach the wafer
30, whereby an image having, as described above, a
contrast of approximately 90 %, is formed. Further,
10 the 0th-order diffracted light component and the
primary diffracted light components travel through
the positions having substantially equal distances
from the optical axis AX on the pupil surface 51 of
the projection optical system 29, and hence the focal
15 depth is also great.

The case of the patterns having the
periodicity in the direction x has been described so
far. The patterns having the periodicity in the
direction y are, however, available. The directions
20 of the gratings are not limited to the above-mentioned
but may include, e.g., a slant direction in accordance
with the reticle patterns. Two pieces of light
transmissive substrates formed with the repetitive
diffraction grating patterns 13a shown in Fig. 2 are
25 disposed so that the pattern surfaces confront each
other. Two flat plates are relatively rotated about
the optical axis of the illumination optical system,

1 and arbitrary patterns may be formed by adjusting
the relative positions of the respective patterns.
Further, the repetitive patterns assuming other
arbitrary configurations may also be available.

5 The diffraction grating patterns 13 may be not only
the rectilinear patterns but also patterns having
the periodic structure, e.g., homocentric grating
patterns (Fresnel zone plate, etc.) and homocentric
elliptical patterns. Additionally, the patterns
10 having arbitrary light-and-shade portions in the
two direction x, y may also be created by use of
liquid crystal and the like. In these cases also,
the spatial filter 16 having the transmissive
portions determined based on the positions of
15 diffracted light may be used.

The diffraction grating pattern plate 12
may be the one in which a light shielding film of
Cr and the like undergoes patterning on the surface
of a transmissive substrate, e.g., a glass substrate.

20 Alternatively, the plate 12 may be the one provided
with so-called phase gratings in which a dielectric
film of SiO_2 or the like is subjected to patterning.
The phase gratings exhibit such advantages that the
0th-order diffracted light component can be
25 restrained, the spatial filter 16 can be also
omitted, and a loss of the light quantity is small.

As discussed above, the incident directions

1 and the incident angles of the (plurality of)
illumination luminous fluxes incident on the reticle
patterns 28 are prescribed corresponding to the
reticle patterns 28. The incident directions and
5 angles can be adjusted arbitrarily by changing the
directivity and the pitch of the diffraction grating
patterns 13a. For example, as explained earlier, the
diffraction grating pattern plate 12 is replaced
with the one having the different pitches, thereby
10 making variable the positions of the luminous fluxes
incident on the Fourier transform surface. It is
therefore possible to attain an arbitrary distribution
of the illumination light quantity on the Fourier
transform surface without causing a considerable
15 loss of the illumination light quantity. As stated
before, the transmitting positions of the luminous
fluxes on the Fourier transform surface are made
variable, whereby the incident angle of the
illumination light to the reticle patterns 28 is also
20 made variable (the angle of the luminous fluxes
incident on the projection optical system is
adjustable to a desired angle). For this reason,
it is feasible to obtain the projection exposure
apparatus having a high resolving power and a smaller
25 loss of the light quantity. The luminous flux
transform member is intended to generate the light
quantity distribution assuming an arbitrary

1 configuration in accordance with the incident angle
to the reticle patterns 28 on the Fourier transform
surface or in the vicinity of this Fourier transform
surface. Eliminated is an adjustment of the relative
5 positional relation with the reticle patterns.

Note that there will be mentioned in detail
the determination about the positions (on which the
light quantity distributions concentrate on the entire
Fourier transform surface) of the luminous fluxes
10 incident on the Fourier transform surface 50.

The following is an explanation of a method
of deteriorating the image by providing optical
elements in the light transmissive portions of the
spatial filter 16 by way of an example of variant
15 form of the means for deteriorating the image.

Transmissive flat plates having different
thicknesses and refractive indices are adhered to
the respective light transmissive portions of the
spatial filter 16. The beams of light penetrating
20 the individual light transmissive portions travel
along the light paths which are each longer by a value
of (diffraction grating pattern plate thickness x
refractive index). If a difference between the
lengths of the light paths of the luminous fluxes
25 penetrating the respective transmissive portions
is larger than a coherent length of the illumination
light, the beams of light penetrating the respective

1 transmissive portions do not interfere with each
other on the reticle pattern surfaces. Namely, it
implies that no image of the diffraction grating
patterns is formed. For instance, if the illumination
5 light is an i-beam (wavelength = $0.365 \mu\text{m}$, wavelength
width = $0.005 \mu\text{m}$) of the mercury lamp, the coherent
length of the illumination light is approximately $27 \mu\text{m}$.
Where the glass having a refractive index of
1.5 is used as the above-described diffraction grating
10 pattern plate, a difference (Δt) between the
thicknesses of the flat plates adhered to the
respective openings is expressed such as:

$$\Delta t \times (1.5 - 1) \geq 27 \mu\text{m}$$

where the refractive index of the air is 1. The
15 difference defined by $\Delta t \geq 54 \mu\text{m}$ may suffice.

Hence, if the glasses individually having a
refractive index of, e.g., 1.5 and thicknesses of
 $1000 \mu\text{m}$, $1060 \mu\text{m}$ (thickness-difference is $60 \mu\text{m}$)
are adhered to the respective openings of the spatial
20 filter illustrated in, e.g., Fig. 3, the interference
fringes on the reticle pattern surfaces - i.e., the
image of the diffraction grating patterns - disappear
(deterioration).

Where the light transmissive flat plates
25 having the different thicknesses and refractive
indices are adhered to the openings of the spatial
filter 16 in this manner, the diffraction grating

1 patterns 13 and the optical member or the light
scattering member 17 may not be oscillated, shifted
or rotated.

5 If a coherence length of the illumination
light is large, and when using, e.g., a laser beam
source, preferably an optical rotatory element such
as crystal may be adhered to one opening of the
spatial filter 16 to rotate a polarizing direction
of the transmission light through approximately 90°.
10 Adhered to other openings are the transmissive flat
plates of glass and the like having substantially
equal length of the light path as that of the optical
rotary element. Where the spatial filter described
above is employed, almost a half of the luminous
15 fluxes with which the reticle pattern surfaces are
irradiated are orthogonal (alternatively, circularly
polarized light in the reverse direction) to each
other in terms of their polarizing directions.
Therefore, the interference fringes - viz., the
20 image of the diffraction grating patterns - are
deteriorated. The diffraction grating patterns 13
are positioned with slight deviations in the optical-
axis direction from the conjugate position to the
reticle patterns 28, with the result that the image
25 of the diffraction grating patterns 13 projected on
the reticle patterns 28 may be deteriorated
(defocused).

1 Deteriorated (homogenized) by the image
deteriorating means on the basis of the above-
described construction are the unnecessary light-and-
shade fringes (the image of the diffraction grating
5 patterns) which are produced by projecting (image-
forming) the diffraction grating patterns serving as
the luminous flux distributing member on the reticle
pattern surfaces through the illumination optical
system. Alternatively, the fringes are averaged in
10 time and then homogenized in terms of the distribution
of the image surface light quantity. An unevenness
of illuminance on the reticle pattern surfaces can be
prevented from being deteriorated. Further, it is
feasible to remarkably reduce the manufacturing costs
15 for the luminous flux transform members without being
influenced by the defects in manufacturing the
luminous flux distributing members.

The diffraction grating pattern plate 12 may
be not only the transmissive pattern plate but also a
20 reflective pattern plate shown in Fig. 8. The optical
member for transforming the illumination light
described above into a plurality of luminous fluxes
and forming an arbitrary light quantity distribution
on the Fourier transform surface 50 is not limited to
25 the diffraction grating pattern plate 12 or 12A.

Fig. 9 is a schematic diagram showing an
arrangement in which a prism 33 formed with a

1 plurality of refractive surfaces is employed as a
member (luminous flux distributing member) for guiding
a plurality of luminous fluxes onto the Fourier
transform surface 50 and forming an arbitrary light
5 quantity distribution on the Fourier transform
surface. The configurations toward the light source
from a relay lens 11 and toward the reticle from a
relay lens 15 are the same as those shown in Fig. 1.
The prism 33 in Fig. 9 is divided into two refractive
10 surfaces with the optical axis AX serving as a
boundary. The illumination light incident upwardly
of the optical axis AX is refracted upwards, whereas
the illumination light incident downwardly of the
optical axis AX is refracted downwards. Hence, the
15 illumination luminous fluxes can be incident on the
Fourier transform surface in accordance with a
refracting angle of the prism 33. The dividing number
of the refractive surfaces is not limited to 2 but may
be any number in accordance with a desired light
20 quantity distribution on the Fourier transform
surface. The dividing positions are not necessarily
symmetric positions with respect to the optical axis
AX.

The incident positions of the illumination
25 luminous fluxes incident on the Fourier transform
surface 50 is made variable by exchanging the prism
33.

1 Further, the prism 33 at this time may be a
polarization beam splitter such as wollaston prism, etc.
In this case, however, the polarizing directions of
the split luminous fluxes are different, and hence
5 the polarization properties may be arranged in one
direction, considering the polarization property of
the resist of the wafer 30. The device, as a matter
of course, incorporates a function to exchange the
prism and the like.

10 Fig. 10 shows an example where a plurality of
mirrors 34a, 34b, 34c, 34d are employed as luminous
flux distributing members. The illumination light
passing through the relay lens system 11 is so
reflected as to be separated into two directions
15 through the primary mirrors 34b, 34c and guided by
the secondary mirrors 34a, 34d. The illumination
light is again reflected and reaches the Fourier
transform surface. Each of the mirrors 34a, 34b, 34c,
34d is provided with a position adjusting mechanism
20 and a mechanism for adjusting an angle of rotation
about the optical axis AX. Based on these mechanisms,
the illumination light quantity on the Fourier
transform surface 50 is arbitrarily made variable.
Further, the mirrors 34a, 34b, 34c, 34d may be plane,
25 convex or concave mirrors. As depicted in Fig. 10,
it is permitted that some luminous fluxes are not
reflected once by the mirrors but the incident

1 directly on the Fourier transform surface 50 from the
relay lens 4. Besides, lenses may be interposed
between the secondary mirrors 34a, 34d and the Fourier
transform surface.

5 Prepared by twos in Fig. 10 are the primary
mirrors 34b, 34c and the secondary mirrors 34a, 34d.
The numerical quantity is not limited to this value.
The mirrors may be disposed appropriately
corresponding to the desired illumination light
10 incident on the Fourier transform surface in
accordance with the reticle patterns 28. All the
mirrors are, as the necessity arises, constructed
to retreat up to such positions that the illumination
luminous fluxes strike on the mirrors.

15 Fig. 11 illustrates an example where a beam
splitter is employed as a luminous flux distributing
member. The configurations toward the light source
from the relay lens 11 and towards the reticle from
the space filter 16 are the same as those shown in
20 Fig. 1. As illustrated in Fig. 11, the illumination
light traveling through the relay lens 11 is split
into two luminous fluxes LA1, LA2 by means of a beam
splitter 38 provided in the illumination optical
system. The luminous fluxes LA1, LA2 are distributed
25 as those having a certain magnitude (thickness) on the
Fourier transform surface 50 through lens systems 39,
40 and plane parallels 41, 42. The lens systems 39,

1 40 are properly selected, whereby a magnitude of the
illumination light quantity distribution on the
Fourier transform surface 50 can be arbitrarily set.
The plane parallels 41, 42 are minutely movable
5 (inclined) by drive systems 43, 44. The distributed
positions of the luminous fluxes distributed on the
Fourier transform surface 50 can be minutely
adjustable. The drive systems 43, 44 are constructed
of motors, gears or piezoelements and so on.

10 The luminous flux distributing member may
involve the use of a waveguide member such as optical
fibers and the like. Fig. 12 is a schematic diagram
in a case where an optical fiber bundle 35 is used
as a luminous flux distributing member. The
15 configurations towards the light source from the relay
lens 11A and towards the reticle from the spatial
filter 16 are the same as those shown in Fig. 1. The
illumination light emerging from the light source and
penetrating the relay lens 11A is incident via an
20 incident portion 351 on the optical fiber bundle 35
while being adjusted to a predetermined numerical
aperture (NA). The illumination luminous fluxes
incident via the incident portion 351 on the optical
fiber bundle 35 are split into a plurality of luminous
25 fluxes and exit a plurality of exit portions 35a, 35b.
The plurality of exit portions 35a, 35b are provided
in positions eccentric from the optical axis AX on the

1 Fourier transform surface (pupil surface of the
illumination optical system) 50. Only the luminous
fluxes which exit only the exit portions 35a, 35b are
formed in close proximity to the Fourier transform
5 surface.

It is therefore possible to form an arbitrary
distribution of the illumination light quantity in the
vicinity of the Fourier transform surface even by
using the optical fiber bundle 35 as in the same way
10 with the above-mentioned diffracting grating pattern
plate 12.

At this time, lenses (e.g., filed lenses) may
be interposed between the exit portions 35a, 35b of
the optical fiber bundle 35 and the spatial filter
15 16.

As discussed above, the incident angles of
the illumination light falling on the reticle 27 and
the reticle patterns 28 are determined by the
positions (eccentric from the optical axis AX) of the
20 exit portions 35a, 35b within the plane vertical to
the optical axis AX. For this reason, the exit
portions 35a, 35b are independently movable with the
aid of movable members 36a, 36b for adjusting the
positions of the exit portions 35a, 35b within the
25 Fourier transform surface.

Next, an embodiment of the movable portions
movable on the fiber exit portions will be explained

1 with reference to Figs. 12 and 13. Fig. 12 is a
sectional view, as in Fig. 1, taken substantially
in the direction vertical to the optical axis. Fig.
13 is a plan view taken substantially in the optical-
5 axis direction.

Employed herein are four pieces of fiber exit
portions 35a, 35b, 35c, 35d as a means for creating
an arbitrary light quantity distribution on the
Fourier transform surface 50. The respective fiber
10 exit portions are in discrete positions eccentric from
the optical axis AX and are disposed at substantially
equal distances from the optical axis AX. Turning to
Figs. 12 and 13, the fiber exit portions 35a, 35b,
35c, 35d are stretchable and contractible in the
15 direction perpendicular to the optical axis by means
of drive elements such as motors and gears which are
incorporated into the movable members 36a, 36b, 36c,
36d through support bars 37a, 37b, 37c, 37d. The
movable members 36a, 36b, 36c, 36d themselves are also
20 movable in the circumferential direction about the
optical axis along a fixed guide 36e. Therefore, the
individual fiber exit portions 35a, 35b, 35c, 35d are
independently movable in the intra-plane direction
vertical to the optical axis. Namely, these exit
25 portions are independently movable to arbitrary
positions (so as not to overlap with each other).
The respective positions (within the plane vertical

1 to the optical axis AX) of the fiber exit portions
35a, 35b, 35c, 35d shown in Figs. 12 and 13 are
changed preferably in accordance with the reticle
patterns to be transferred. Exit surfaces of the exit
5 portions 35a, 35b may be formed with the light
scattering members such as diffusion plates and
with aperture spots for regulating the apertures.

The luminous flux distributing member may be
replaced with the spatial filter 16 provided in the
10 vicinity of the Fourier transform surface. In this
case, however, a loss of the light quantity increases.

Note that the foregoing luminous flux
distributing means (such as the optical fibers and
the beam splitter) depicted in Figs. 9 through 12 are
15 all intended to prepare the light quantity
distribution in close proximity to the Fourier
transform surface of the reticle patterns. The
positions (conjugate relation) in which the exit
portions of the luminous distributing means may be
20 arbitrarily set.

Given is a case where the plural beams of
illumination light come from the luminous flux
distributing member. However, one luminous flux
may be incident on the position eccentric by a
25 predetermined quantity from the optical axis AX on
the Fourier transform surface. For instance, one
luminous flux may fall on the Fourier transform

1 surface 50 by providing one exit portion of the fiber
35 shown in Fig. 12.

Now, the incident positions of the luminous
flux distributing member onto the Fourier transform
5 surface are determined (changed) preferably according
to the reticle patterns to be transferred. A method
of determining the positions in this case is that,
as explained referring to Fig. 41, the incident
position (incident angle ϕ) of the illumination
10 luminous fluxes from the exit portions to the reticle
patterns may be set to obtain the effects of improving
the resolving power and focal depth which are optimal
to the degree of fineness (pitch) of the patterns to
be transferred.

15 By exemplifying a case where the optical fibers
are used herein as a luminous flux transform member,
there will be next explained a concrete example of
determining the position (gravity position of the
light quantity distribution created by one luminous
20 flux incident on the Fourier transform surface) of
the luminous flux passing above the Fourier transform
surface. The explanation will be given with reference
to Figs. 15A through 15D. Figs. 15A to 15D are
diagrams schematically illustrating the exit surfaces
25 of the elements from the exit portions 35A, 25B to the
reticle patterns 28. The exit surfaces coincide with
the Fourier transform surface 50. At this time, the

1 lenses or a lens group for bringing both of them into
a Fourier transform relation are expressed in the form
of a single lens 26. Further, it is assumed that f is
the distances from the principal point on the side of
5 the fly eye lens to the exit surface and from the
principal point on the side of the reticle of the lens
26 to the reticle patterns 28.

Figs. 15A and 15C are diagrams each showing
an example of some patterns formed in the reticle
10 patterns 28. Fig. 15B illustrates the central
position (the optimum position of a peak value of the
light quantity distribution on the Fourier transform
surface) on the Fourier transform surface (or the
pupil surface of the projection optical system) which
15 is optimal to the reticle patterns of Fig. 15A. Fig.
15D is a diagram illustrating the central position
(gravity position of the light quantity distribution
created by one luminous flux incident on the Fourier
transform surface) of the exit portions optical to
20 the reticle patterns of Fig. 15C. Fig. 15A depicts
so-called one-dimensional line-and-space patterns
wherein the transmissive portions and light shielding
portions are arranged with equal widths to assume a
striped configuration in the direction Y and also
25 regularly arranged at pitches P in the direction X .
At this time, the central position of one exit portion
(surface illuminant) is, as illustrated in Fig. 15B,

1 in an arbitrary position on a line segment $L\alpha$ or $L\beta$ in
the direction Y which is presumed within the Fourier
transform surface. Fig. 15B is a diagram showing a
Fourier transform surface 50A associated with the
5 reticle patterns 28 which is viewed substantially in
the optical-axis direction AX . Coordinate systems
 X, Y within the Fourier transform surface 50A are
identical with those in Fig. 15, wherein the reticle
patterns 28 are observed in the same direction. Now,
10 the distances α, β from the center C through which the
optical axis AX passes to the respective line segments
 $L\alpha, L\beta$ have a relation such as $\alpha = \beta$. These distances
are equal such as: $\alpha = \beta = f \cdot (1/2) \cdot (\lambda/P)$, where λ
is the exposure wavelength. When the distances α, β
15 are expressed as $f \cdot \sin\phi$, $\sin\phi = \lambda/2P$. This is
identical with the numerical value explained in Fig.
40. Hence, the plurality of exit portions are
provided, and the respective central positions of the
individual exit portions are on the line segments
20 $L\alpha, L\beta$. On this assumption, it follows that the two
diffracted light components i.e., the 0th-order
diffracted light component generated from the
illumination light coming from the respective exit
portions and any one of the (\pm) primary diffracted
25 light components pass through the position having
almost equal distances from the optical axis AX on
the pupil surface 51 of the projection optical system

1 with respect to the line-and-space patterns.

Therefore, as discussed above, the focal depth with respect to the line-and-space patterns (Fig. 15A) can be maximized, and the high resolving power is also

5 obtainable. Note that one exit portion (surface illuminant) to be formed on the line segments $L\alpha$, $L\beta$ may suffice if a positional deviation concomitant with the defocus of the wafer 30 is ignored.

Next, Fig. 15C shows a case where the reticle
10 patterns are so-called isolated spatial patterns, wherein P_x is the X-directional (crosswise) pitch of the patterns, and P_y is the Y-directional (vertical) pitch thereof. Fig. 15D is a diagram illustrating the optimum position of the exit portion in that case.
15 The positional/rotational relationship associated with Fig. 15C are the same as those of Figs. 15A and 15B. As seen in Fig. 15C, when the illumination light falls on the two-dimensional patterns, the diffracted light components are generated in the two-dimensional
20 directions corresponding to periodicity ($X : P_x$, $Y : P_y$) in the two-dimensional directions of the patterns. Even in the two-dimensional patterns shown in Fig. 15C, if the 0th-order diffracted light component and any one of the (+) primary diffracted
25 light components in the diffracted light have almost equal distances from the optical axis AX on the projection optical system pupil surface 51, the

1 focal depth can be maximized. In the patterns of
Fig. 15C, the X-directional pitch is P_x . Therefore,
as shown in Fig. 15, if the centers of the respective
exit portions are on the line segments L_α , L_β defined
5 such as $\alpha = \beta = f \cdot (1/2) \cdot (\lambda/P_x)$, the focal depth can
be maximized with respect to the X-directional
elements of the patterns. Similarly, if the centers
of the respective exit portions are on line segments L_γ ,
 L_ϵ defined such as $\gamma = \epsilon = f \cdot (1/2) \cdot (\lambda/P_y)$, the focal
10 depth can be maximized with respect to the Y-
directional elements of the patterns.

When the illumination luminous fluxes
corresponding to the exit portions disposed in the
respective positions shown thus in Figs. 15B and 15D
15 are incident on the reticle patterns 28, the 0th-order
diffracted light component D_0 and any one of a (+)
primary diffracted light component D_p and a (-)
primary diffracted light component D_m pass through
the light paths having the equal distances from
20 optical axis AX on the pupil surface 51 within the
projection optical system 29. Consequently, as
stated in conjunction with Fig. 4, it is possible
to actualize a projection type exposure apparatus with
a high resolving power and a large focal depth. Only
25 two examples of the reticle patterns 28 shown in Figs.
15A and 15B have been considered so far. Even in
other patterns, however, the attention is paid to

1 the periodicity (degree of fineness) thereof. The
respective exit portions may be disposed in such
positions that two luminous fluxes i.e., the 0th-order
diffracted light component and any one of the (+)
5 primary diffracted light component and the (-) primary
diffracted light component travel through the light
paths having the substantially equal distances from
the optical axis AX on the pupil surface 51 within the
projection optical system. Provided in the pattern
10 examples of Figs. 15A and 15C are the patterns having
a ratio (duty ratio), 1 : 1, of the line portion to
the spatial portions. Consequently, (+) primary
diffracted light components become intensive in the
diffracted light generated. For this reason, the
15 emphasis is placed on the positional relation between
one of the (+) primary diffracted light components
and the 0th-order diffracted light component. In the
case of being different from the duty ratio of 1 : 1,
however, the positional relation between other
20 diffracted light components, e.g., one of (+) secondary
diffracted light components and the 0th-order
diffracted light component may be set to give the
substantially equal distances from the optical axis
AX on the projection optical system.

25 If the reticle patterns 28, as seen in Fig.
15D, contain the two-dimensional periodic patterns,
and when paying the attention to one specific

1 0th-order diffracted light component, there probably
exist higher-order diffracted light components than
the primary light components which are distributed in
the X-direction (the first direction) and in the Y-
5 direction (the second direction) about the single 0th-
order diffracted light component on the pupil surface
51 of the projection optical system. Supposing that
the image of the two-dimensional patterns is formed
well with respect to one specific 0th-order diffracted
10 light component, the position of the specific 0th-
order diffracted light component may be adjusted so
that three light components i.e., one of the higher-
order diffracted light components distributed in the
first direction, one of the higher-order diffracted
15 light components and one specific 0th-order diffracted
light component are distributed at the substantially
equal distances from the optical axis AX on the pupil
surface 51 of the projection optical system. For
instance, the central position of the exit portion
20 in Fig. 15D is arranged to coincide with any one of
points $P\xi$, $P\eta$, $P\kappa$, $P\mu$. The points $P\xi$, $P\eta$, $P\kappa$, $P\mu$
are all intersections of the line segment $L\alpha$ or $L\beta$
(the optimum position to the X-directional
periodicity, i.e., the position in which the 0th-
25 order diffracted light component and one of the (\pm)
primary diffracted light components in the X-direction
have the substantially equal distances from the

1 optical axis on the pupil surface 51 of the projection
optical system) and line segments, LY, LE (the optimum
positions to the Y-direction periodicity). Therefore,
those positions are the light source positions optimal
5 to either the pattern direction X or the pattern
direction Y.

Presumed in the above-described arrangement
are the patterns as two-dimensional patterns having
the two-dimensional directivities at the same place
10 on the reticle. The aforementioned method is
applicable to a case where a plurality of patterns
having different directivities exist in different
positions in the same reticle patterns.

Where the patterns on the reticle have the
15 plurality of directivities and degrees of fineness,
the optimum position of the secondary illuminant
image, as explained earlier, corresponds to the
respective directivities and degrees of fineness of
the patterns. Alternatively, however, the secondary
20 illuminant image may be in the averaged position
of the respective optimum positions. Besides, this
averaged position may also undergo load averaging
in which a weight corresponding to the significance
and degree of fineness of the pattern is added.

25 (One or a plurality of) luminous fluxes with
which the reticle 27 is irradiated are incident on
the reticle 27 with an inclination to the optical

1 axis AX of the projection optical system 29. At this
time, if the direction of the light quantity gravity
of those illumination luminous fluxes is inclined to
the optical axis AX, there arises such a problem that
5 the position of a transferred image shifts in the
intra-wafer-surface direction during minute defocusing
of the wafer 30. To prevent this problem, the
direction of the light quantity gravity of the
illumination luminous fluxes distributed on the
10 Fourier transform surface is made perpendicular to
the reticle patterns 28, i.e., parallel to the optical
axis AX. For example, where the optical fibers are
employed as a luminous flux transform member, the
arrangement is effected to make zero a vector sum
15 (integration) of a product of the exit portion's
position (positional vector within the Fourier
transform surface from the optical axis AX of the
gravity of the light quantity distribution created by
the exit portions) and the transmission light
20 quantity. Note that when using the diffraction
grating pattern plate 12 as a member for forming the
light quantity distribution on the Fourier transform
surface, this condition is automatically satisfied.
The following is a definite example of the above-
25 mentioned distribution of the illumination light
quantity. The number of luminous fluxes is set to $2m$
(m is the natural number), and positions of the

1 m-number luminous fluxes are arbitrarily set, while
positions of remaining m-numbered luminous fluxes
may be set in symmetry with respect to the optical
axis AX and the former m-numbered luminous fluxes
5 as well.

Besides, the exit surfaces of the exit
portions 35a, 35b may be formed with aperture stops
for regulating the apertures and with light scattering
members such as diffusion plates, etc.

10 The number of the plurality of the exit
portions is not limited to 4 but may be arbitrarily
set corresponding to the reticle patterns 28. For
instance, three pieces of exit portions are available.
The center of a single piece of secondary illuminant
15 image formed by one exit portion is set in the
position eccentric by a quantity corresponding to the
reticle patterns 28 from the optical axis AX. The
secondary illuminant image may be changed depending on
the time.

20 In addition, if necessary, the reticle 27 may
be arranged so as not to undergo an irradiation of
the illumination light from specific one of the exit
portions. For example, supposing that a broken line
circle 50A in Fig. 13 is formed corresponding to a
25 size of the pupil surface 51 of the projection optical
system 29, the light shielding member is provided
outwardly of this broken line circle 50A in

1 combination with the Fourier transform surface 50
(Fig. 1) of the illumination system. When the
unnecessary exit portions retreat to this light
shielding portion (outside the broken line circle
5 50A of Fig. 13), it is possible to obtain a desired
number of exit portions.

A diameter (numerical aperture of one beam
of illumination light on the Fourier transform surface
of the illumination system) of opening of each exit
10 portion is preferably set so that a so-called σ -value
(a ratio of the numerical aperture of the illumination
optical system which is estimated in the projection
optical system to the numerical aperture of the
projection optical system) becomes approximately 0.1
15 to 0.3 per luminous flux. If the σ -value is 0.1 or
under, the image fidelity declines, whereas if this
value is 0.3 or above, the increasing effect of the
focal depth is reduced.

Fig. 16 is a diagram schematically
20 illustrating a construction of the projection type
exposure apparatus in accordance with a second
embodiment of this invention. The principal
configuration of the aligner is the same as that of
Fig. 1. The same members as those in Fig. 1 are
25 marked with the same reference numbers. In this
embodiment, the means for forming an arbitrary light
quantity distribution on the Fourier transform surface

1 involves the use of a movable optical member such as
a reflection mirror and the like in place of the
luminous flux distributing member used in the first
embodiment.

5 The lens system 4 is irradiated with a
luminous flux L1 emitted from the light source 1
via the elliptical mirror 2. The luminous flux L1
is shaped into a substantially collimated luminous
flux L2 by means of the lens system 4 and becomes a
luminous flux L3 through the fly eye lens 7 and the
10 aperture stop 8. A reflector 54 is irradiated with
the luminous flux L3 via the lens system 11. A field
stop 20 is irradiated with a luminous flux L4
reflected by the reflector 54 through lens systems 15,
19. Further, a half-mirror 24A is irradiated with
15 a luminous flux L5 passing through the field stop
20 via a lens system 22. The luminous flux L5
reflected by the half-mirror 24A then falls on the
reticle 27 at a predetermined incident angle through a
lens system (principal condenser lens) 26. The
20 configuration towards the wafer from the lens system
26 is the same as that of Fig. 1 (the first
embodiment), the description is therefore omitted.
Note that the aperture stop 8 is a stop for
25 determining a coherent factor σ of the illumination
luminous flux as in the first embodiment.

On the other hand, the luminous flux

1 penetrating the half-mirror 24A is condensed by a lens
system 56 and undergoes a photoelectric conversion in
a light quantity meter 57 such as a semiconductor
sensor and the like. A light quantity signal S
5 obtained from the light quantity meter 57 is
transmitted as an electric signal to a control circuit
58. Based on the light quantity signal S, the control
circuit 58 gives instructions to a shutter drive unit
53 for driving a shutter 52 and to drive elements 55A,
10 55B for driving the reflector 54. When the shutter
drive unit 53 is operated, the luminous flux 2 is cut
off by the shutter 52, thereby stopping the exposure.
Note that this embodiment has a construction to
control the shutter drive unit 53 and the drive
15 elements 55A, 55B by use of the light quantity meter
57. The effects of the present invention are not
varied by the arrangement that the control is
performed simply in accordance with the exposure time
without providing the light quantity meter 57.

20 Based on the construction given above, the
incident surface of the fly eye lens 7, the field
stop 20, the reticle patterns 28 (pattern surfaces) of
the reticle 27 and the wafer 30 are conjugate to each
other. Further, the exit surface of the fly eye lens
25 7, the Fourier transform surface 50 of the reticle
27 and the pupil surface 51 of the projection optical
system 29 are also conjugate to each other.

1 Note that for making the illuminance on the
reticle surface 27 homogeneous, the incident surface
of the fly eye lens 7 is positioned to have an image
forming relation with the reticle 27. On the other
5 hand, the exit surface of the fly eye lens 7 is
positioned corresponding to the Fourier surface
(pupil surface) with the reticle patterns 28 of the
reticle 27 serving as object surfaces.

 The reflector 54 is, as described above, in the
10 position substantially conjugate to the reticle 27 and
rotatable about two axes orthogonal to each other on,
e.g., a reflecting surface. the reflector 54 is rotated
by the drive elements 55A, 55B such as motors,
piezoelements and the like.

15 Turning to Fig. 16, the reflected light L4
traveling towards the luminous flux L4a is shown by a
solid line. The reflected luminous flux L4a is allowed
to travel in the direction of, e.g., a luminous flux
L4b by changing a rotary angle of the reflector 54.
20 That is, one secondary illuminant image at the exit end
of the fly eye lens 7 is shifted on the Fourier
transform surface 50. It is also, as a matter of
course, possible to provide a component movable in the
direction perpendicular to the sheet of Fig. 16.

25 In the thus constructed exposure apparatus,
the reflector 54 is driven by the drive elements 55A,
55B and set in predetermined positions. Thereupon,

1 the luminous flux L4 whose principal beam is coaxial with
the optical axis AX of the illumination optical system is
changed into luminous fluxes L4a, L4b whose principal
beams are inclined to the optical axis AX. These luminous
5 fluxes L4a, L4b are condensed respectively in positions
different from the optical axis AX in the vicinity of the
Fourier transform surface 50 of the reticle 27. For this
reason, a luminous flux L5 (corresponding to the luminous
flux L4a) with which the reticle 27 is irradiated is
10 obliquely incident on the reticle 27. As explained in
Fig. 41, the high resolving power and the large focal
depth are attainable. Supposing that an illumination
luminous flux L5a for illuminating the reticle 27
is always incident on the reticle 27 at a constant
15 incident angle, however, the light quantity gravity
(in other words, the principal beam of the luminous
flux L5a) in the incident direction of the luminous
flux L5a by which the image is formed on the wafer
30 comes to assume a slant state (non-telecentric
20 state) to the wafer 30. Namely, it may happen that
the image position deviates sideways within the wafer
surface with a minute deviation (defocus) of the
wafer 30 in the direction of the optical axis AX.
Taken in this embodiment is such a measure for
25 preventing this lateral deviation that the incident
angle of the illumination luminous flux on the reticle
27 is changed by the reflector 54. Hence, after

1 performing the illumination with a predetermined
amount of exposure by use of the luminous flux L5a
incident at a certain incident angle ϕ , and
thereafter the reflector 9 is moved. The illumination
5 is effected this time to have the same amount of
exposure as the above-mentioned by using the luminous
flux L5b incident at an incident angle $-\phi$. The lateral
deviation of the light quantity gravity incident on
the wafer from a normal line of the wafer surface is
10 thereby offset with the exposure at incident angle
 $+\phi$ and the exposure at the incident angle $-\phi$. The
projection type exposure apparatus in this embodiment
is provided with the light quantity meter 57 for
measuring the quantity of light with which the
15 reticle is irradiated. It is therefore feasible to
easily make constant the exposure quantity at the
incident angle $+\phi$ and the exposure quantity at the
incident angle $-\phi$ and further equalize these values.
Even in the case of controlling the exposure time
20 instead of providing the light quantity meter, it
is similarly possible to make the respective exposure
quantities constant and equalize these values.
An arbitrary light quantity distribution on the
Fourier transform surface 50 can be formed in this
25 manner by use of the movable reflector.

In accordance with this embodiment, the
reflector⁵⁴ defined as a movable optical member

1 existing in the position substantially conjugate to
the reticle 27 is moved. It can be therefore
considered that if the field stop 20 is disposed
closer to the light source than the reflector 54, a
5 positional relation between the reticle 27 and the
field stop 20, though small, deviates with the
movement of the reflector 54. Hence, the field stop
20 is desirably is placed closer to the reticle 27
than the reflector 54.

10 If there is an insufficient compensation of
chromatic aberration of the optical elements in the
projection optical system 29 and the illumination
optical system (from the lens system 26 to the light
source 1 in the Figure), a wavelength selecting
15 element such as a band-pass filter is used in the
illumination luminous flux, e.g., the luminous flux
L2. Alternatively, the reflection member such as
the elliptical mirror 2 may involve the use of a
multilayer dielectric mirror to enhance a reflectivity
20 of only the specific wavelength.

It is to be noted that even in the case of
transferring circuit patterns by the projection type
exposure apparatus in this embodiment, as in the
first embodiment, the ratio, i.e., a so-called
25 coherent factor σ , of the numerical aperture of the
illumination luminous flux to the numerical aperture
on the part of the photo mask of the projection

1 optical system is preferably 0.1 to 0.3. Hence,
the fly eye lens 7 and the aperture stop 8 are set
so that $\sigma = 0.1$ to 0.3.

Fig. 17 is a diagram depicting a configuration
5 of a variant form 1 of the projection type exposure
apparatus in this embodiment. This variant form
employs a lens system as a movable optical member.
However, the constructions toward the light source
from the fly eye lens 7 and toward the reticle from
10 the Fourier transform surface (pupil surface of the
illumination optical system) 50 are the same as those
in Fig. 16, and the description is therefore omitted.
The luminous flux emerging from the fly eye lens falls
on a lens system 59a having a positive power via the
15 lens system 11 on a lens system 59b having a negative
power. The lens systems 59a, 59b are disposed in
close proximity to the surface conjugate to the
reticle 27. A sum of the powers of the lens systems
59a, 59b becomes 0. The lens systems 59a, 59b are
20 movably respectively by the lens drive members 55c,
55d within the surface vertical to the optical axis AX.
The luminous flux penetrating the lens systems 59a,
59b movably by the drive members 55c, 55d becomes a
luminous flux having the principal beam different from
25 the optical axis AX of the illumination optical system.
The luminous fluxes is condensed in a position
different from the optical axis AX on the Fourier

1 transform surface 50.

Referring to Fig. 17, the lens systems 59a, 59b are moved almost an equal distance in the direction opposite to the optical axis. As a result, 5 the luminous flux penetrating the lens systems 59a, 59b is incident on the lens system 15 at a given angle inclined to the optical axis AX. If the positions of the lens systems 59a, 59b are changed by the lens drive members 55c, 55d, the luminous flux exited 10 can be oriented in an arbitrary direction. Note that the lens drive members 55c, 55d are controlled by a control circuit 58.

A new lens system having a positive power is disposed closer to the reticle 27 than the lens 15 system 59b and movably by the lens drive member. Further, a total of powers of the lens systems 59a, 59b and of the newly added lens system having the positive power may be arranged to be 0. Similarly, a lens system having a negative power is disposed 20 closer to the light source than the lens system 59a. A total of powers of the lens systems 59a, 59b and of the newly added lens system having the negative power may be also arranged to be 0. Note that the arrangement of the lens system in which that position 25 is variable is not limited to only the combinations given above. A permissible arrangement is that the lens group composed of a plurality of lens elements

1 has a power total of 0, and the illumination luminous
flux can be oriented in an arbitrary direction by
moving the respective lens elements. The lens
elements to be driven are not specified. Similarly,
5 the lens elements capable of orienting the
illumination luminous flux in an arbitrary direction
are satisfactory.

Fig. 18 is a diagram schematically
illustrating a second variant form of the projection
10 type exposure apparatus in this embodiment. In this
variant form, the movable optical element involves
the use of a photo transmitting means such as fibers.
An arbitrary light quantity distribution is formed
on the Fourier transform surface. However, the
15 constructions toward the light source from the fly
eye lens 7 and toward the reticle from the lens system
19 are the same as those in Fig. 16, and the
description is therefore omitted. The Fourier
transform surface 50 is linked via the photo
20 transmitting means such as optical fibers 60 to
the exit side of the fly eye lens 7. Hence, the
exit surface of the fly eye lens 7 corresponds to the
Fourier transform surface 50. The exit side of the
optical fibers 60, i.e., the portion on the side of
25 the Fourier transform surface 50, is movable by a
drive member 55e. The illumination luminous flux
(illuminant image) can be thereby distributed in

1 arbitrary positions within the Fourier transform
surface 50. The drive member 55e is, as in the same
way with the variant form 1 of this embodiment,
controlled by the control circuit 58.

5 Next, an exposure method by use of the
exposure apparatus in the second embodiment will be
described with reference to Figs. 19A and 19B.

Figs. 19A and 19B are flowcharts each showing
the exposure method in the embodiment of this
10 invention. A difference between Figs. 19A and 19B
lies in whether the exposure is stopped or not when
driving the reflector 54. In advance of the
exposure, the shutter 52 is in such a status as to
cut off the luminous flux L2. Determined herein
15 are the number of positional changes of the reflector
54, coordinates of the respective positions of the
reflector and exposure quantities for the respective
coordinates (step 101). As stated before, however,
if a so-called light quantity gravity of the
20 illumination light when the luminous flux L5
corresponding to each position of the reflector 54
falls on the reticle 27 deviates from the optical
axes AX of the illumination optical system and the
projection optical system 20, there exists a
25 possibility of causing a lateral deviation of the
transferred image due to a very small defocus of
the wafer 30. It is thus required to determine the

1 respective positions of the reflector 54 and the
illumination light quantities (exposure quantities)
for illumination according to the respective positions
of the reflector 54 so that the light quantity gravity
5 coincides with the optical axis AX. This may be
accomplished by determining, when one pattern exposure
is completed by effecting 2m-time (m is the natural
number) exposing processes, the coordinates of the
reflector 54 effecting the m-time exposures thereof.
10 Further, the coordinates of the reflector effecting
the remaining m-time exposures may be set in symmetry
with respect to the optical axis AX and the incident
luminous flux in a case where the incident luminous
flux is associated with the former m-time exposures.
15 Incidentally, a method of determining the coordinates
of the reflector 54 which is performing the exposing
processes at respective angles in a plurality of
positions may be prescribed so that the light quantity
distribution (positional coordinates of the luminous
20 fluxes) on the Fourier transform surface 50 has the
conditions explained in the first embodiment with
reference to Figs. 14 and 15. More specifically,
the position of the reflector 54 may, when
transferring the patterns depicted in Fig. 15A, be
25 determined so that the center (principal beam) of the
illumination luminous flux L4a or L4b reflected by
the reflector 54 coincides on the line segment L₀ or

1 L β on the Fourier transform surface 50. When
transferring the patterns shown in Fig. 15B, the
central position of the illumination luminous flux
reflected by the reflector 54 may be determined to
5 coincide on the line segment L α or L β and the line
segment LY or L ϵ . The optimum position in this case
includes four points P ξ , P η , P κ , P μ .

Next, operating instructions are issued from
the control circuit 58 to the drive members 55a, 55b,
10 and the reflector 54 is set in a predetermined first
position (step 102). The operator inputs the first
position by means of an input unit incorporated into
the control circuit 58. Alternatively, the control
circuit 58 is allowed to determine the first position
15 of the reflector 54 on the basis of the information
on the circuit patterns 28 on the reticle 27, the
information being inputted by the operator through the
input unit. A necessary total exposure quantity E
is likewise inputted by the operator through the input
20 unit. The control circuit 58 is, even when being
inputted by the operator, permitted to decide specific
degrees of exposures which are effected in the
respective positions of the reflector 54. As in the
first embodiment, the information described above
25 may be obtained by reading the bar codes BC provided
on the mask.

Subsequently, the action enters the actual

1 exposing process. The reflector 54 is almost fixed
in the first position previously determined. In
this state, the control circuit 58 issues an
instruction of "Open shutter" to the shutter drive
5 unit 53. A shutter 52 is opened, and the exposure
is started (step 103). The reticle is illuminated
with the illumination luminous flux. Consequently,
the reticle patterns 28 are transferred on the wafer
30. At this moment, some illumination luminous fluxes
10 passing through the half-mirror 24A are received and
converted photoelectrically by the light quantity meter
57. When an integrated value of the light quantity
signal S thereof reaches a predetermined value, i.e.,
an exposure quantity corresponding to the previously
15 determined first position (step 104), or just before
reaching that value, the control circuit 58 gives
the operating instructions to the drive members 55a,
55b. The position of the reflector 54 is thereby
changed to a predetermined second position (step 105).
20 Note that when the integrated value (integrated light
quantity) of the light quantity signal S, as shown in
Fig. 19B, reaches the predetermined value, the shutter
52 is temporarily stopped (step 105a). The reflector
54 is moved after stopping the exposure. The
25 reflector 54 is substantially fixed in the
predetermined position, and thereafter the shutter 52
is opened (step 105b). Then, the exposure may resume.

1 When the integrated value of the light quantity
signal S comes to the predetermined value in the second
position of the reflector 54 (step 106), or just before
reaching this value, the reflector 54 is moved in the same
5 manner as before. The reflector 54 is substantially fixed
in a third position, and the exposure continues. At this
time also, the shutter 52 is temporarily closed as in the
previous case, and the exposure may be stopped.

 Thereafter, the position of the reflector 54
10 is likewise changed to m-numbered positions, thus
performing the exposures. When the integrated value
of the light quantity signal S comes to the preset
total exposure quantity E in the m-th position of
the reflector 54 (step 107), the shutter 52 is closed,
15 thus completing the exposure.

 Incidentally, where E_1, E_2, \dots, E_m ($\sum E_i =$
 $E, 1 \leq i \leq m$) are the exposure quantities in the
respective positions, the exposure in the first
position is ended when the integrated value of the
20 light quantity signal S reaches E_1 or just before
reaching it. The exposure in the second position
is ended when the integrated value reaches $(E_1 + E_2)$
or just before reaching it. Namely, the exposure in
the arbitrary n-th position among the exposures in
25 the first through m-th positions comes to an end
when the integrated value reaches $\sum E_i$ ($1 \leq i \leq n$).

 Adopted is a method of stopping the exposure

1 by closing the shutter 52 during a movement of the
reflector 54. In this case, the integrated value
is reset to 0 during a stoppage of the exposure.
Thereafter, the exposure resumes, and when the
5 integrated value of the light quantity signal S
reaches the predetermined value E_n , the exposure in
the arbitrary n-th position may be ended.

The exposures in accordance with the second
embodiment of this invention are thus completed.

10 Therefore, the wafer 30 is carried in parallel within
the surface vertical to the optical axis AX by a wafer
stage 31. The exposures may be newly effected in
other exposure regions of the wafer 30. Besides, the
exposures may be performed in the exposed region by
15 replacing the reticle 27 while superposing other
circuit patterns thereon. Note that when newly
effecting the exposures in other positions of the
wafer 30, the sequence of positions of the reflector
54 may be so reversed as to start with the m-th
20 position and end up with the first position.

Based on the above-described exposure method,
the reflector 54 is moved while making the exposure
continue. In this case, the illumination light
emerging from directions other than the predetermined
25 one is incident on the reticle 27 during the movement
of the reflector 54. This causes a possibility where
the effects to obtain the foregoing high resolving

1 power and large focal depth will decline. For
preventing this, a space filter having transmissive
portions only in predetermined positions is provided
in the vicinity of the Fourier transform surface 50
5 between the lens systems 15, 19 shown in Figs. 16.
In this spatial filter, the transmissive portions
are formed in the predetermined positions eccentric
from the optical axis AX on the Fourier transform
surface 50, while the light shielding portions are
10 formed in other positions. The predetermined
positions of the transmissive portions are those
through which the illumination luminous fluxes L4a,
L4b generated from the reflector 54 in the respective
positions for obtaining the desired resolving power
15 and focal depth pass above the Fourier transform
surface 50. Diameters of the respective transmissive
portions serve to determine σ -values of the individual
illumination luminous fluxes. Hence, this diameter
is optically equivalent to the aperture stop 8 on the
20 surface of the exit side of the fly eye lens 7 which
has been previously determined; viz., the diameter
is set considering a relation in magnification between
the surface (conjugate to the Fourier transform
surface 50) on the exit side of the fly eye lens 7
25 and the Fourier transform surface 50. The diameter
of the specific transmissive portion may be smaller
than the above-mentioned (equivalent) diameter.

1 Namely, the σ -value of the specific luminous flux
among the luminous fluxes incident on the reticle 27
may be decreased.

A light scattering member such as a lemon
5 skin filter and the like may be provided on the
Fourier transform surface 50. This light scattering
member is capable of making unsharp defects and dusts
on the movable optical member. It is therefore
possible to prevent the unevenness of illuminance on
10 the reticle 27 which is caused by the dusts and
defects. Note that an image forming relation between
the reticle 27 and the movable optical member
(reflector 54) becomes unsharp due to the light
scattering member but does not exert any adverse
15 influence on the effects of the present invention.

A third embodiment of the present invention
will next be explained with reference to the drawings.
In accordance with the first and second embodiment
described above, the luminous flux transform member
20 for forming an arbitrary light quantity distribution
on the Fourier transform surface and the movable
optical member are interposed between the reticle
and the optical integrator of the fly eye lens or the
like. In this embodiment, however, the luminous flux
25 transform member and the movable optical member are
interposed between the optical integrator and the
light source, thereby improving the illuminance

1 homogenizing effect.

Fig. 20 illustrates an outline of a projection type exposure apparatus (stepper) suitable for the third embodiment of this invention. Provided is a 5 diffraction grating pattern plate 12 as an optical member (a part of an input optical system of this invention) for concentrating the illumination light on a light-source-side focal surface 72a of a fly eye lens 72. Note that the same members as those 10 in the first and second embodiments are marked with the like symbols.

The illumination luminous fluxes emerging from the mercury lamp 1 are condensed at a second focal point of the elliptical mirror 2. Thereafter, 15 the diffraction grating pattern plate 12 is irradiated with the condensed luminous flux via a mirror 6 and a lens system 71 of a relay system. An illumination method at this time may be the Kohler illumination method or the critical illumination method. However, 20 the critical illumination method is desirable in terms of obtaining a more intensive light quantity. The diffracted light generated from the diffraction grating pattern plate 12 is incident in concentration on the position eccentric from the optical axis AX 25 of the light-source-side focal surface 72a (incident surface) of the fly eye lens 72 with the aid of the relay lens 73. It is herein assumed that the

1 0th-order and (+) primary diffracted light components
are generated. At this moment, the light-source-side
focal surface 72a of the fly eye lens 72 and the
diffraction grating pattern plate 12 have
5 substantially a Fourier transform relation through the
relay lens 71. Note that the illumination light on
the diffraction grating pattern plate 12 is
illustrated as collimated luminous fluxes in Fig.
20, but they are actually divergent luminous fluxes.
10 Hence, the luminous flux incident on the light-source-
side focal surface 72a of the fly eye lens 72 has a
certain magnitude (thickness). Correspondingly, the
exit luminous flux from a reticle-side focal surface
72b of the fly eye lens 72 in accordance with the
15 incident light flux on the light-source-side focal
surface 72a also has a certain magnitude.

On the other hand, the reticle-side focal
surface 72b of the fly eye lens 72 is so disposed
as to be substantially coincident with the Fourier
20 transform surface (pupil conjugate surface) of the
reticle patterns 28.

The respective lens elements of the fly eye
lens 72 depicted in Fig. 20 are double convex lens
elements, shown therein is a case where the light-
25 source-side focal surface 72a coincides with the
incident surface, and the reticle-side focal surface
72b coincides with the exit surface. The lens

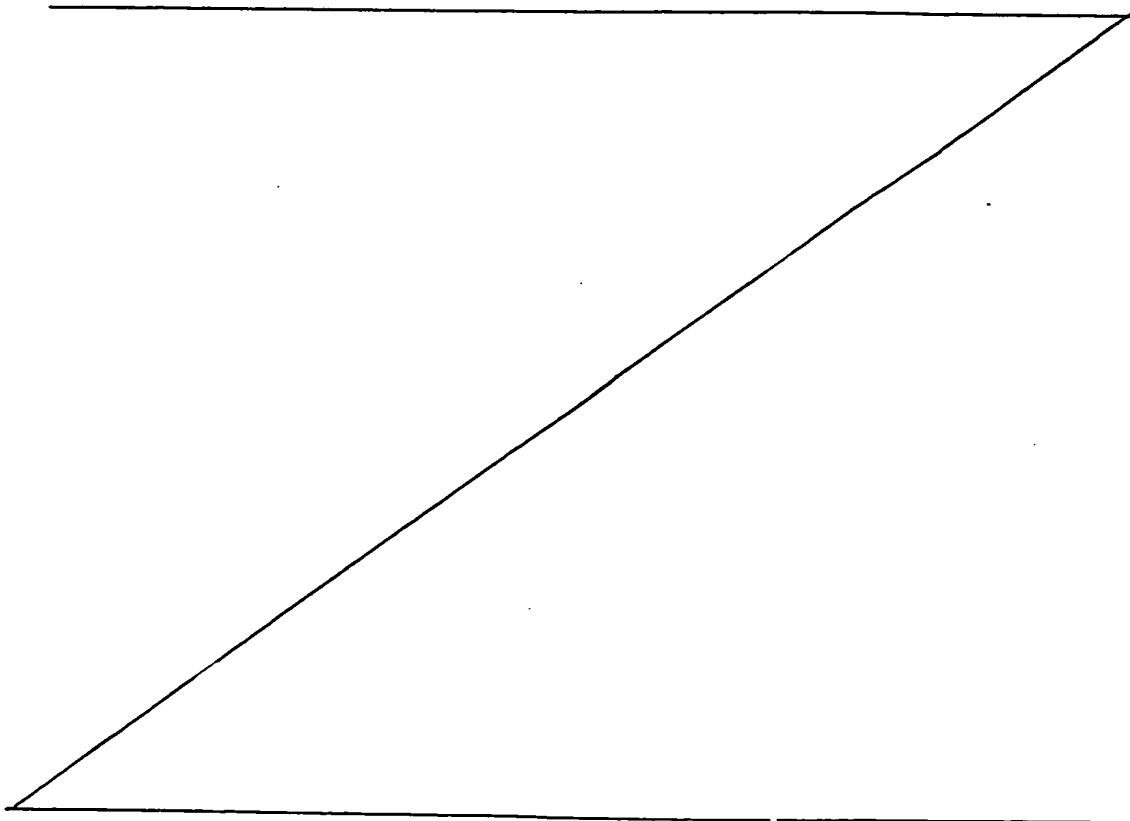
1 elements of the fly eye lens do not strictly fulfill
this relationship. Those lens elements may be plane-
convex lens elements, convexo-plane lens elements
or plane-concave lens elements. The fly eye lens
5 is composed of one or more lens elements.

Note that the light-source-side focal surface
72a of the fly eye lens 72 and the reticle-side focal
surface 72b have, as a matter of course, the Fourier
transform relation. Hence, in the example of Fig.
10 1, the reticle-side focal surface 72b of the fly
eye lens 72, i.e., the fly eye lens exit surface,
has the image forming (conjugate) relation with
the diffraction grating pattern plate 12.

15

20

25



1 Now, the reticle 27 is illuminated to have
a homogeneous illuminating distribution with the luminous
flux emerging from the reticle-side focal surface 72b
of the fly eye lens 72 via condenser lenses 74, 75
5 and a mirror 24. In accordance with this embodiment,
the spatial filter 16 composed of a metal plate or
the like and bored with two openings corresponding
to the (\pm) primary diffracted light components from
the diffraction grating pattern plate 12 is disposed
10 in the vicinity of the reticle-side focal surface 72b
(exit side) of the fly eye lens 72. The 0th-order
diffracted light component from the diffraction grating
pattern plate 12 is thereby cut off. The illumination
light with which the reticle patterns 28 are illuminated
15 are therefore limited to the one having two secondary
illuminant images in the positions eccentric from the
optical axis AX on the reticle-side focal surface 72b
of the fly eye lens 72. The diffraction grating pattern
plate 12 is employed as an optical member for concentrat-
20 ing the illumination light on the light-source-side
focal surface 72a of the fly eye lens 72. Formed are
the two secondary illuminant images symmetric with
respect to the optical axis AX. Hence, the illumination
light with which the reticle patterns 28 are illuminated
25 are limited to only the luminous fluxes having specific
incident angles on the reticle patterns 28. As discussed
above, the image of the diffraction grating pattern

1 plate 12 is formed on the reticle-side focal surface
72b of the fly eye lens 72. The reticle-side focal
surface 72b and the reticle pattern surfaces 28 have
the Fourier transform surface relation. This eliminates
5 such possibilities that the image of the diffraction
grating pattern plate 12 itself is formed on the reticle
27 to deteriorate the illuminance homogeneity, and
further there is produced the ununiformity due to the
dusts and the defects of the diffraction grating pattern
10 plate 12. Note that the spatial filter 16 is provided
in close proximity to the light-source-side focal surface
72b of the fly eye lens 72, i.e., on the side of the
exit surface of the fly eye lens 72; but this filter
may be provided on the reticle-side focal surface 72a,
15 i.e., on the side of the incident surface.

The diffracted light generated from the reticle
patterns 28 on the thus illuminated reticle 27 is,
as in the same way explained with reference to Fig.
40, condensed and image-formed by the telecentric
20 projection optical system 29. The image of the reticle
patterns 28 is transferred on the wafer 30.

The diffraction grating pattern plate 12 may
be not only the transmissive pattern plate similar
to that in the first embodiment but also a reflective
25 pattern plate. If the diffraction grating pattern
plate 12 exhibits a reflective property, as illustrated
in Fig. 21, a reflective diffraction grating pattern

1 plate 12A is, as depicted in Fig. 8, illuminated with
the illumination luminous flux from the relay lens
71. The diffracted light reflected and diffracted
therein may be incident on the fly eye lens 72. The
5 constructions toward the light source from the relay
lens 71 and toward the reticle from the fly eye lens
72 are the same as those of Fig. 20. At this time,
as in the first embodiment, the incident directions
and incident angles of the illumination luminous fluxes
10 (plural) incident on the reticle patterns 28 of the
reticle 27 are determined depending on the reticle
patterns 28. The incident directions and angles are
arbitrarily adjustable by changing directivities and
itches of the diffraction grating pattern plates 12,
15 12A. For instance, diffraction grating patterns 5,
5a are replaced with those having different pitches,
thereby making variable the illumination light incident
on the light-source-side focal surface 72a of the fly
eye lens 72 and further making variable a distance
20 of the secondary illuminant image from the optical
axis AX on the reticle-side focal surface 72b of the
fly eye lens 72. It is therefore feasible to make
variable the incident angle of the illumination light
on the reticle patterns 28 of the reticle 27. As in
25 the first embodiment, when the diffraction grating
pattern plates 12, 12A are made rotatable (e.g., through
90°) in an arbitrary direction within the surface

1 vertical to the optical axis AX, it is possible to
correspond to the case where the pitch direction of
the line-and-space patterns of the reticle patterns
28 is different from the directions x, y. Further,
5 the relay lens 73 may come under a zoom lens system
(such as an afocal zoom expander, etc.) consisting
of a plurality of lens elements, and the condensing
position can be varied by changing the focal distance.
At this time, however, it is required to keep substan-
10 tially the Fourier transform relation between the
diffraction grating pattern plate 12 or 12A and the
light-source-side focal surface 72a of the fly eye
lens 72. The optical member for concentrating the
illumination light on the light-source-side focal surface
15 72a of the fly eye lens 72 described above is not limited
to the diffraction grating pattern plate 12 or 12A.

As depicted in Fig. 22, the movable optical
member shown in the second embodiment, e.g., a movable
plane mirror 54 is disposed instead of the reflective
20 diffraction grating pattern plate 12A illustrated in
Fig. 21. Provided also is a drive member 55a such
as a motor for making the plane mirror 54 rotatable.
The plane mirror 54 is rotated or oscillated by the
drive member 55a. The illumination light is incident
25 on the light-source-side focal surface 72a of the fly
eye lens 72, whereby the secondary illuminant image
of the reticle-side focal surface 72b of the fly eye

1 lens 72 can be varied according to the time. If the
plane mirror 54 is rotated to a plurality of proper
angular positions during the exposing process, the
secondary illuminant image of the reticle-side focal
5 surface 72b of the fly eye lens 72 can be formed in
arbitrary configurations. Note that when using this
type of movable reflection mirror 54, the relay lens
system 73 may be omitted. By the way, the spatial
filter 16 depicted in Fig. 22 is provided on the side
10 of the incident surface of the fly eye lens 72 but
may be, as in the same way with Fig. 20, provided on
the side of the exit surface.

The optical member for concentrating the illumina-
tion light on the light-source-side focal surface
15 72a of the fly eye lens 72 may involve the use of the
beam splitter shown in Fig. 11, the optical fibers
of Figs. 12 and 19, the prism of Fig. 9, the plurality
of mirrors of Fig. 10 and the optical member of Fig.
17.

20 Fig. 23 is a schematic diagram wherein an optical
fiber bundle 35 is employed. The constructions toward
the light source from the relay lens 71 and toward
the reticle from the fly eye lens 72 are the same as
those shown in Fig. 20. Respective exit portions 35a,
25 35b of the optical fiber bundle 35 are disposed in
positions corresponding to the reticle patterns 28
in the vicinity of the light-source-side focal surface

1 72a of the fly eye lens. At this time, lenses (e.g.,
field lenses) may be interposed between the respective
exit portions 35a, 35b of the optical fiber bundle
35 and the fly eye lens 72. Further, there may be
5 given the Fourier transform relation between the light-
source-side focal surface 72a of the fly eye lens and
the light exit surfaces of the optical fiber exit
portions 35a, 35b owing to the lenses interposed
therebetween. As in the first embodiment, the respec-
10 tive exit portions (or the lenses between the exit
portions 35a, 35b and the fly eye lens 72) are made
movable one-dimensionally or two-dimensionally within
the surface perpendicular to the optical axis by means
of the drive member such as a motor, etc.. The
15 illumination light incident on the light-source-side
focal surface of the fly eye lens is thereby made
variable. The secondary illuminant image on the reticle-
side focal surface 72b of the fly eye lens is also
made variable.

20 Fig. 24 shows an example of using a prism 33
having a plurality of refraction surfaces as an optical
member for concentrating the illumination light on
the light-source-side focal surface 72a of the fly
eye lens 72. The illumination luminous fluxes can
25 be incident on the light-source-side focal surface
72a of the fly eye lens 72 in accordance with refraction
angles of the prism 33. The constructions toward the

1 light source from the relay lens 71 and toward the
reticle from the fly eye lens 72 are the same as those
of Fig. 20. The incident position of the illumination
luminous flux incident on the light-source-side focal
5 surface 72a of the fly eye lens is made variable by
replacing the prism 33. In place of the prism 33,
a reflection mirror having differently-angled reflection
surfaces is used and, as illustrated in Fig. 22, disposed,
thereby eliminating the necessity for the drive member
10 55a. The device, as a matter of course, incorporates
a function to exchange the prism and the like. When
employing this type of prism also, the relay lens system
73 may be omitted.

Fig. 25 shows an example where a plurality
15 of mirrors 34a - 34d are used as optical members for
condensing the illumination light on the light-source-
side focal surface 72a of the fly eye lens 72. The
constructions toward the light source from the relay
lens 71 and toward the reticle from the fly eye lens
20 72 are the same as those of Fig. 20. Provided in the
respective mirrors 34a - 34d are position adjusting
mechanisms and mechanisms for adjusting an angle of
rotation about the optical axis AX by which a illumina-
tion light quantity distribution on the light-source-
25 side focal surface 72a of the fly eye lens 72 is made
arbitrarily variable. Besides, the prism 33 may be
combined with the movable plane mirror 54 or with the

1 mirrors 34a - 34d.

Further, the optical member for concentrating the illumination light on the light-source-side focal surface 72a of the fly eye lens 72 may be replaced
5 with the spatial filter 16 provided in the vicinity of the light-source-side focal surface 72a of the fly eye lens. The components in the embodiments shown in Figs. 20 through 25 may be combined with the spatial filter 16. At this time, the number of openings of
10 the spatial filter 16 is not 1 but may be arbitrary numbers corresponding to the reticle patterns 28.

Fig. 26 is a diagram depicting a construction of the projection type exposure apparatus in a further embodiment of this invention. The mirror 24, the
15 condenser lens 75, the reticle 27 and the projection optical system 29 are the same as those shown in Fig. 20. As a construction toward the light source from the fly eye lens 72, any one of the examples shown in Figs. 20 through 25 and the example in which the
20 spatial filter 16 is provided in the vicinity of the light-source-side focal surface 72a of the fly eye lens 72. A spatial filter 16A formed with arbitrary openings (transmissive portions, or further semitrans-
25 missive portions) is provided in close proximity to the reticle-side focal surface 72b of the fly eye lens 72. The illumination luminous flux emerging from the fly eye lens 72 is thereby regulated. The Fourier

1 transform surface of a reticle-side focal surface 72b
of the fly eye lens 72 with respect to a relay lens
76A is defined as a conjugate surface to the reticle
patterns 28, and hence a variable field stop (reticle
5 blind) 76 is provided therein. The illumination luminous
flux is Fourier-transformed again by the relay lens
76B and reaches a conjugate surface (Fourier surface)
50B of the reticle-side focal surface 72B of the fly
eye lens 72. The above-mentioned spatial filter 16A
10 may be provided on the Fourier surface 50B. The illumi-
nation luminous flux from the fly eye lens 72 is further
guided to the reticle 27 with the aid of the condenser
lenses 76B, 75 and the mirror 24. Note that if there
exists a system for condensing the illumination light
15 on the position eccentric by a quantity from the optical
axis which is determined corresponding to the reticle
patterns 28 on the light-source-side focal surface
72A of the fly eye lens 72, the spatial filter may
not be disposed in the position of the optical member
20 16A or 50B.

In this case also, the field stop (reticle
blind) 76 is usable.

Shown is the example where the plural beams
of illumination light come from the optical member
25 for concentrating the illumination light on the light-
source-side focal surface 72a of the fly eye lens 72
described above. However, one luminous flux may be

1 incident on the position eccentric by a predetermined
quantity from the optical axis AX. For example, one
exit portion of the fiber bundle 35 shown in Fig. 23
is prepared, while one luminous flux may be incident
5 on the light-source-side focal surface 72A of the fly
eye lens 72.

In all the embodiments of Figs. 20 through
26, a diameter of one opening of the spatial filters
16, 16A is desirably set so that a ratio, a so-called
10 σ -value, of a numerical aperture for the reticle 27
associated with the illumination luminous fluxes
penetrating the openings to a reticle-side numerical
aperture (NA_R) of the projection optical system 29
is approximately 0.1 to 0.3.

15 For satisfying the condition of the σ -value
determined by one illumination luminous flux incident
on the light-source-side focal surface 72a of the fly
eye lens 72, a function to make the σ -value variable
may be given to an optical member for concentrating
20 the illumination light on the light-source-side focal
surface 72a of the fly eye lens and making variable
a light quantity distribution in the vicinity of the
focal surface 72a in place of the spatial filter 16A
disposed close to the reticle-side focal surface 72b
25 of the fly eye lens 72. For instance, the spatial
filter 16 is disposed on the light-source-side focal
surface 72a of the fly eye lens, and the σ -value per

1 luminous flux may be determined by the diameter of
the opening thereof. Concomitantly, it is possible
to further optimize the σ -value and NA in the form
of the projection system by providing a variable
5 aperture stop (NA regulating stop) in the vicinity
of the pupil (incident pupil or exit pupil) 51 within
the projection optical system 29. The spatial filter
16 also exhibits an effect to shield unnecessary luminous
fluxes among the fluxes generated from the optical
10 member for condensing the illumination light on the
light-source-side focal surface 72a of the fly eye
lens 72. This filter further exhibits an effect to
reduce the quantity of light which reaches the wafer
by decreasing a transmissivity of the opening with
15 respect to specific luminous fluxes.

It is preferable to determine (change) the
incident position (position of the secondary illuminant
image on the light-source-side focal surface 72b of
the fly eye lens 72) of (one or plural) illumination
20 luminous flux(es) on the light-source-side focal surface
72a of the fly eye lens 72 in accordance with the reticle
patterns to be transferred. In this case, the method
of determining the position is that, as stated earlier,
the incident position (incident angle ϕ) of the illumina-
25 tion luminous flux from the fly eye lens 72 on the
reticle patterns may be set to obtain the effect of
improving the resolving power and focal depth that

1 are optimal to the degree of fineness (pitch) of the
patterns to be transferred. A concrete example of
the positional determination of the secondary illuminant
image (surface illuminant image) is the same as the
5 determining method explained in the first embodiment
with reference to Figs. 14 and 15. It is assumed that
the central position (the optimum position of the gravity
of the light quantity distribution created by one
secondary illuminant image) of one secondary illuminant
10 image is, as illustrated in Fig. 15B, on the Y-direc-
tional line segment $L\alpha$ presumed within the Fourier
transform surface. Alternatively, it is assumed that
the centers of the respective secondary illuminant
images are placed on arbitrary positions on the line
15 segment $L\beta$, or, as illustrated in Fig. 15D, on the
line segments $L\alpha$, $L\beta$ defined such as $\alpha = \beta = f \cdot (1/2) \cdot$
 (λ/P_x) or on the line segments $L\gamma$, $L\epsilon$ defined such
is $\gamma = \epsilon = f \cdot (1/2) \cdot (\lambda/P_y)$. Based on these assump-
tions, the focal depth can be maximized. As in the
20 first embodiment, the 0th-order diffracted light
component D_0 coming from the reticle patterns 28 and
any one of the (+) primary diffracted light component
 D_p and the (-) primary diffracted light component D_m
may be arranged to pass through the light paths having
25 the equal distances from the optical axis AX on the
pupil surface 51 within the projection optical system
29. If the reticle patterns 28, as seen in Fig. 15D,

1 contain the two-dimensional periodic patterns, and
when paying the attention to one specific 0th-order
diffracted light component, there probably exist higher-
order diffracted light components than the primary
5 light components which are distributed in the X-direction
(the first direction) and in the Y-direction (the second
direction) about the single 0th-order diffracted light
component on the pupil surface 51 of the projection
optical system. Supposing that the image of the two-
10 dimensional patterns is formed well with respect to
one specific 0th-order diffracted light component,
the position of the specific 0th-order diffracted light
component may be adjusted so that three light components
i.e., one of the higher-order diffracted light
15 components distributed in the first direction, one
of the higher-order diffracted light components distrib-
uted in the second direction and one specific 0th-order
diffracted light component are distributed at the
substantially equal distances from the optical axis
20 AX on the pupil surface 51 of the projection optical
system. For instance, the central position of the
exit portion in Fig. 15D is arranged to coincide with
any one of points $P\xi$, $P\eta$, $P\kappa$, $P\mu$. The points $P\xi$, $P\eta$,
 $P\kappa$, $P\mu$ are all intersections of the line segment $L\alpha$
25 or $L\beta$ (the optimum position to the X-directional
periodicity, i.e., the position in which the 0th-order
diffracted light component and one of the (\pm) primary

1 diffracted light components in the X-direction have the
substantially equal distances from the optical axis
on the pupil surface 51 of the projection optical system)
and line segments L_y , L_x (the optimum positions to
5 the Y-directional periodicity). Therefore, those
positions are the light source positions optimal to
either the pattern direction X or the pattern direction
Y.

Note that in this embodiment, an arbitrary
10 light quantity distribution can be, as in the first
embodiment, formed on the Fourier transform surface
by controlling the luminous flux transform member and
the movable optical member on the basis of the informa-
tion of bar codes and the like.

15 A light scattering member such as a diffusion
plate and an optical fiber bundle are provided in close
proximity to the light-source-side focal surface 72a
of the fly eye lens 11, thereby homogenizing the
illumination light. Alternatively, the illumination
20 light may be homogenized by employing an optical
integrator such as a further fly eye lens (hereinafter
referred to as the other fly eye lens) separately from
the fly eye lens 72 used in the embodiments of the
present invention. At this time, the other fly eye
25 lens is disposed preferably closer to the light source
(lamp) 1 than the optical member e.g., the diffraction
grating pattern plate 12 or 12A shown in Figs. 20 and

1 21 for making variable the illumination light quantity
distribution in the vicinity of the light-source-side
focal surface 72a of the fly eye lens 72. A sectional
configuration of each lens element of the other fly
5 eye lens is desirably a regular hexagon rather than
a square (rectangle).

Fig. 27 illustrates a configuration ambient
to a wafer stage of the projection exposure apparatus
applied to the respective embodiments of this invention.
10 A beam 80A obliquely strikes on an interior of a projec-
tion field region on the wafer 30 in the projection
optical system 29. Provided is an auto-focus sensor
of an oblique incidence system which receives a reflected
beam 80B. This focus sensor detects a deviation in
15 the optical-axis direction AX between the surface of
the wafer 30 and the best image forming surface of
the projection optical system 29. A motor 82 of a
Z-stage 81 mounted with the wafer 30 is servo-controlled
so that the deviation becomes zero. The Z-stage 81
20 is thereby moved slightly in the vertical directions
(optical-axis directions) with respect to an XY-stage
83, wherein the exposure is executed invariably in
the best focus state. In the exposure apparatus capable
of this focus controlling process, the Z-stage 81 is
25 moved with such a velocity characteristic as to be
controlled in the optical-axis directions during the
exposing process. An apparent focal depth can be

1 thereby further enlarged. This method is attainable
by any type of steppers on condition that the image
side (wafer side) of the projection optical system
29 is telecentric.

5 Fig. 28 shows light quantity (dose) distributions
in the optical-axis directions which are obtained within
the resist layers with a movement of the Z-stage 81
during the exposure or abundance probabilities. Fig.
28B shows velocity characteristics of the Z-stage 81
10 for obtaining the distribution illustrated in Fig.
28A. Referring to Figs. 28A and 28B, the axis of
ordinate indicates wafer positions in Z-direction
(optical-axis direction). The axis of abscissa of
Fig. 28A indicates the abundance probability. The
15 axis of abscissa of Fig. 28B indicates a velocity of
the Z-stage 81. In the same Figures, a position Z_0
is the best focus position.

The abundance probabilities are herein arranged
to be substantially equal maximal values in two positions
20 $+Z_1$, $-Z_1$ spaced vertically from the position Z_0 by
a theoretical focal depth $\pm \Delta Dof$ of the projection
optical system 29. In a range from $+Z_3$ to $-Z_3$ there-
between, the abundance probabilities are restrained
down to small values. For this purpose, the Z-stage
25 81 moves up and down equally at a low velocity V_1 in
the position $-Z_2$ when starting a release of the shutter
within the illumination system. Immediately after

1 the shutter has been fully opened, the Z-stage is
accelerated up to a high velocity V2. While the Z-
stage 81 moves up and down at the velocity V2, the
abundance probabilities are restrained down to the
5 small values. Just when reaching the position +Z3,
the Z-stage 81 starts decelerating down to the low
velocity V1. The abundance probability comes to the
maximal value in the position +Z1. At this moment,
a closing command of the shutter is outputted almost
10 simultaneously. The shutter is completely closed in
the position +Z2.

In this manner, the velocity of the Z-stage
81 is controlled so that the optical-axis-directional
light quantity distributions (abundance probabilities)
15 of the exposure quantities imparted to the resist layers
of the wafer 30 are arranged to be the maximal values
at the two points spaced away by approximately a width
($2 : \Delta D_0 f$) of the focal depth. Although a contrast
of the patterns formed on the resist layers is a little
20 bit reduced, the uniform resolving power can be obtained
over a wide range in the optical-axis directions.

The above-described cumulative focal point
exposure method is applicable in much the same manner
to the projection exposure apparatus which adopts the
25 special illumination method shown in this embodiment.
The apparent focal depth is enlarged by a quantity
corresponding substantially to a product of an enlarge

1 portion obtained by the illumination method of this
invention and an enlarged portion obtained by the
cumulative focal point exposure method. Besides, since
the special illumination method is adopted, the resolving
5 power itself also increases. For instance, the minimum
line width possible to exposure by combining an i-
beam stepper (NA 0.42 of the projection lens) which
is contracted one-fifth that the prior art with a phase
shift reticle is approximately 0.3 to 0.35 μm . An
10 enlargement rate of the focal depth is about 40% at
the maximum. In contrast, the special illumination
method according to the present invention is incorporated
into the i-beam stepper, and a test is carried out
with the ordinary reticle. As a result, the minimum
15 line width of 0.25 ~ 0.3 μm is obtained. Obtained
also is much the same enlargement rate of the focal
depth as that in using the phase shift reticle.

A fourth embodiment of the present invention
will next be described. Fig. 29 depicts a projection
20 type exposure apparatus (stepper) in the fourth
embodiment of this invention. The fly eye lens is
divided into a plurality of fly eye lens groups. The
light quantity distribution is focused on each of the
fly eye lens groups. The diffraction grating pattern
25 plate 12 is provided as an optical member (a part of
the input optical system of this invention) for focusing
the light quantity distribution of the illumination

1 light on each of light-source-side focal surfaces 91a
of the fly eye lens groups 91A, 91B. Note that the
constructions toward the light source from the relay
lens system 71 and toward the wafer 30 from the spatial
5 filter 16 are the same as those of Fig. 20, and the
same members are marked with the like symbols.

The diffracted light generated from the diffrac-
tion grating pattern plate 12 is incident in concentra-
tion on each of the fly eye lens groups 91A, 91B via
10 the relay lens 73. At this moment, the light-source-
side focal surfaces 91a of the fly eye lens groups
91A, 91B and the diffraction grating pattern plate
12 have substantially the Fourier transform relation
through the relay lens 73.

15 On the other hand, reticle-side focal surfaces
91b of the fly eye lens groups 91A, 91B are disposed
in an intra-surface direction perpendicular to the
optical axis AX so as to coincide substantially with
the Fourier transform surface (pupil conjugate surface)
20 of the reticle patterns 28. Each of the fly eye lens
groups 91A, 91B is independently movable in the intra-
surface direction vertical to the optical axis AX and
held by a movable member (position adjusting member
in the present invention) for making the lens group
25 movable. The detailed explanation thereof will be
given later.

The individual fly eye lens groups 91A, 91B

1 desirably assume the same configuration and are composed
of the same material (refractive index). Respective
lens elements of the individual fly eye lens groups
91A, 91B are double-convex lenses as in the third
5 embodiment. Given therein is the example where the
light-source-side focal surface 91a coincide with the
incident surface, and the reticle-side focal surface
91b coincide with the exit surface. The fly eye lens
elements may not strictly satisfy this relation but
10 may be plano-convex lenses, convexo-plane lenses or
plano-concave lenses. Note that the light-source-
side focal surfaces 91a of the fly eye lens groups
and the reticle-side focal surfaces thereof have, as
a matter of course, the Fourier transform relation.
15 Hence, in the example of Fig. 29, the reticle-side
focal surfaces 91b of the fly eye lens groups — i.e.,
the exit surfaces of the fly eye lens groups 91A, 91B
— have an image forming (conjugate) relation to the
diffraction grating pattern plate 12.

20 Now, the reticle 27 is illuminated in a homo-
geneous illuminance distribution with the luminous
fluxes emitted from the reticle-side focal surfaces
91b of the fly eye lens groups 91A, 91B through the
condenser lenses 74, 75 and the mirror 24. In accordance
25 with this embodiment, the spatial filter 16 is disposed
on the exit side of the fly eye lens groups 91A, 91B,
thereby cutting off the 0th-order diffracted light

1 components from the diffraction grating pattern plate
12. The openings of the spatial filter 16 correspond
to the respective positions of the fly eye lens groups
91A, 91B. For this reason, the illumination light
5 quantity distributions in the vicinity of the reticle-
side focal surfaces 91b of the fly eye lens groups
91A, 91B can be made zero in portions other than the
positions of the fly eye lens groups 91A, 91B. There-
fore, the illumination light with which the reticle
10 patterns 28 are illuminated is limited to the luminous
fluxes (from the secondary illuminant images) emitted
from the respective fly eye lens groups 91A, 91B. Hence,
the luminous fluxes incident on the reticle patterns
are limited to those having specific incident angles
15 (plural) thereon.

Note that in the embodiment, each of the fly
eye lens groups 91A, 91B is movable, and the openings
of the spatial filter 16 are correspondingly movable;
or alternatively the spatial filter 16 itself has to
20 be exchangeable (the spatial filter 16 will be mentioned
later). The illumination luminous fluxes are diffracted
by use of the foregoing diffraction grating pattern
plate 12. The diffracted light components are concen-
trated on the specific positions (fly eye lens groups)
25 within the light-source-side focal surfaces of the
fly eye lens groups 91A, 91B. On this occasion, the
concentrated positions are varied depending on the

1 pitch and the directivity of the diffraction grating
pattern plate 12. Therefore, the pitch and the
directivity of the diffraction grating pattern plate
12 are determined to concentrate the illumination light
5 on the positions of the fly eye lens groups 91A, 91B.

As discussed above, the image of the diffraction
grating pattern plate 12 is formed on the reticle-
side focal surface 91b of the fly eye lens 91. As
in the third embodiment described above, however, the
10 reticle pattern surfaces 28 and the reticle-side focal
surfaces 91b of the fly eye lens groups 91A, 91B have
the Fourier transform relation. There is no possibility
wherein the illumination intensity distribution on
the reticle 27 is unhomogenized, or the illuminance
15 homogeneity is deteriorated.

The diffraction grating pattern plate 12 may,
as explained in the third embodiment referring to Fig.
21, be not only the transmissive pattern plate but
also the reflective pattern plate.

20 If the diffraction grating pattern plate 12
is reflective, as illustrated in Fig. 30, the diffracted
light components reflected by the reflective diffraction
grating pattern plate 12A are concentrated in the
vicinity of the fly eye lens groups 91A, 91B through
25 the relay lens 73. Incidentally, the diffraction grating
pattern plate 12 or 12A is exchangeable with a plate
having a different pitch so that the illumination light

1 can be concentrated in the vicinity of the respective
fly eye lens groups 91A, 91B even when the individual
fly eye lens groups 91A, 91B move. The diffraction
grating pattern plate 12 or 12A may be rotatable in
5 an arbitrary direction within the surface vertical
to the optical axis AX. In this case, however, the
Fourier transform relation between the diffraction
grating pattern plate 12 or 12A and the light-source-
side focal surfaces 91a of the fly eye lens groups
10 91A, 91B should be kept.

By the way, referring to Fig. 29, as in the
first embodiment, there are provided a main control
system 58 for generalizing and controlling the device,
a bar code reader 61, a keyboard 63 and a drive system
15 (motor, gear train, etc.) such as movable members for
moving the fly eye lens groups 91A, 91B. Registered
beforehand in the main control system 58 are names
of a plurality of reticles dealt with by the stepper
and stepper operating parameters corresponding to these
20 names. When the bar code reader 61 reads reticle bar
codes BC, the main control system 58 outputs, to the
drive system 92, the previously registered information
on the moving positions (within the Fourier transform
surface) of the fly eye lens groups 91A, 91B as one
25 of the operating parameters corresponding to the names.
The positions of the fly eye lens groups 91A, 91B are
thereby adjusted to form the optimum light quantity

1 distributions described in the first embodiment. The
operations given above can be also executed even by
inputting the commands and data directly from the
keyboard 63.

5 The optical members (input optical system)
are not limited to the diffraction grating pattern
plates 12, 12A, these optical members being intended
to concentrate the light quantity distributions over
the light-source-side focal surfaces of the fly eye
10 lens groups 91A, 91B on the portions in the vicinity
of the individual fly eye lens positions. As in the
cases shown in Figs. 22 - 25 in accordance with the
third embodiment, the movable plane mirror, the optical
fibers, the prism and the reflection mirror are available.

15 Fig. 31 shows the case where the movable plane
mirror 54 is employed as an input optical system. The
constructions toward the light source from the relay
lens system 71 and toward the reticle from the fly
eye lens group 91 are the same as those of Fig. 29.
20 The plane mirror 54 is rotated to a plurality of angular
positions during the exposure, thereby making it pos-
sible to concentrate the light quantity distributions
over the light-source-side focal surfaces 91a of the
fly eye lens groups 91A, 91B on only the portion vicinal
25 to the position of one fly eye lens group of the plural-
ity of the fly eye lens groups. Note that when using
this type of movable plane mirror 54, the relay lens

1 system 73 may be omitted. Further, when each of the
fly eye lens groups 91A, 91B moves, angular coordinates
of the plurality of angular positions of the plane
mirror 54 are changed, and the reflected luminous fluxes
5 may be concentrated in the vicinity of the position
of the fly eye lens group in a new position. Incidental-
ly, the spatial filter 16 illustrated in Fig. 31 is
provided on the side of the incident surfaces of the
fly eye lens groups 91A, 91B but may be provided on
10 the side of the exit surfaces as seen in Fig. 29.

Fig. 32 shows a case of using the optical fibers
of the input optical system. The exit portions 35A,
35B provided corresponding to the number of the fly
eye lens groups 91A, 91B are constructed integrally
15 with the respective fly eye lens groups in the close
proximity to the light-source-side focal surfaces 91a
of the fly eye lens groups 91A, 91B.

The exit portions 35A, 35B (or the lenses between
the exit portions 35 and the fly eye lens groups 91)
20 are one-dimensionally or two-dimensionally movable
within the surface vertical to the optical axis by
means of the drive members such as motors. Even when
the individual fly eye lens groups 91A, 91B are gathered
up, the illumination luminous fluxes can be concentrated
25 in the vicinity of the position of each of the fly
eye lens groups after being moved.

Fig. 33 shows a case of employing the prism

1 33 formed with a plurality of refractive surfaces as
an input optical system. The illumination light can
be concentrated in the vicinity of each of the fly
eye lens groups 91A, 91B in accordance with a refractive
5 angle of the prism 33 on the light-source-side focal
surfaces 91a of the fly eye lens groups 91A, 91B. Even
when the respective fly eye lens groups 91A, 91B move
by exchanging the prism 33, the illumination light
can be exactly concentrated on the position of each
10 of the fly eye lens groups 91A, 91B. The device, as
a matter of course, incorporates a function to exchange
the prism or the like. Where this type of prism is
employed, the relay lens system 73 can be omitted.

Fig. 34 shows a case where a plurality of mirrors
15 are used as an input optical system. When each of
the mirrors 34A - 34D is provided with a position
adjusting mechanism and a mechanism for adjusting an
angle of rotation about the optical axis AX, and even
after the individual fly eye lens groups 91A, 91B have
20 moved, the illumination luminous fluxes can be focused
in the vicinity of the respective fly eye lens groups
91A, 91B. A numerical value of the mirrors is not
limited. The mirrors may be disposed depending on
a numerical value of the fly eye lens groups.

25 Two groups of the fly eye lenses are prepared
throughout the fourth embodiment described above,
however, three or more groups of the fly eye lenses

1 may be of course prepared. Stated also is the optical
member for concentrating the illumination light mainly
on the two portions of the individual fly eye lens
groups. The illumination light is, as a matter of
5 course, concentrated on a plurality of positions cor-
responding to the number of the fly eye lens groups.
In all the embodiments given above, the illumination
light can be concentrated on arbitrary positions
(corresponding to the positions of the fly eye lens
10 groups). The optical member for concentrating the
illumination light on the respective fly eye lens groups
is not limited to the types exemplified in the embodi-
ments but may adopt any other types.

Besides, the spatial filter 16 provided in
15 close proximity to the light-source-side focal surfaces
91a of the fly eye lenses may be employed in combination
with the respective embodiments shown in Figs. 29
through 34. Spatial filters 210, 16 can be, though
not limited to the reticle-side focal surfaces 91b
20 and light-source-side focal surfaces 91a of the fly
eye lens groups, disposed in arbitrary positions. For
example, the spatial filter is disposed suitably between
the above-described two focal surfaces 91a, 91b.

The optical member for concentrating the
25 illumination light only in the vicinity of the individual
fly eye lens groups 91A, 91B is intended to prevent
a loss in quantity of the illumination light with which

1 the reticle 27 is illuminated. The optical member
is not associated directly with the constitution for
obtaining the effects of the high resolving power and
large focal depth that are characteristic of the projec-
5 tion type exposure apparatus according to the present
invention. Hence, the optical member may be only a
lens system having a large diameter enough to make
the illumination light incident in flood on each of
the fly eye lens groups after being adjusted in terms
10 of position.

In the construction, depicted in Fig. 26, of
the third embodiment, the spatial filter 16A may be
provided, or a variable field stop 76 may also be
provided as in the same way with the third embodiment.
15 The spatial filter 16A is placed on the reticle-side
focal surface 91b of the fly eye lens group 91 or in
the vicinity of the conjugate surface thereof, thereby
regulating the illumination luminous fluxes emerging
from the fly eye lens groups 91A, 91B. Note that if
20 there is a system capable of focusing the illumination
luminous fluxes incident on the fly eye lens groups
91A, 91B only thereon effectively, the spatial filter
16 may not be provided on the reticle-side focal surface
91b or in the vicinity of the conjugate surface thereof.

25 For satisfying the condition of the σ -value
($0.1 \leq \sigma \leq 0.3$) determined by one of the fly eye lens
groups, a magnitude (in the intra-surface direction

1 vertical to the optical axis) of the exit end areas
of each of the fly eye lens groups 91A, 91B may be
determined to match with the illumination luminous
fluxes (exit luminous fluxes).

5 A variable aperture stop (equivalent to the
spatial filter 16) is provided in the vicinity of the
reticle-side focal surface 91b of each of the fly eye
lens groups 91A, 91B, and the numerical aperture of
the luminous flux from each of the fly eye lens groups
10 is made variable, thus changing the σ -value. Correspond-
ingly, the variable aperture stop (NA regulating stop)
is disposed close to the pupil (incident pupil or exit
pupil) 51 of the projection optical system 29, thereby
further optimizing the σ -value with respect to NA in
15 the projection system.

The illumination of the luminous fluxes incident
on the respective fly eye lens groups expands to some
extent outwardly of the incident end surfaces of the
fly eye lens groups. Besides, if the distributions
20 in quantity of the light incident on the respective
fly eye lens groups are uniform, the illuminance
homogeneity on the reticle pattern surfaces can be
preferably further enhanced.

Next, an embodiment of the movable portions
25 for making the fly eye lens groups movable will be
explained in conjunction with Figs. 35 and 36.

Fig. 35 is a diagram illustrating the movable

1 portions viewed from the optical-axis direction. Fig.
36 is a diagram showing the same viewed from the direc-
tion vertical to the optical axis.

A plurality of, i.e., four fly eye lens groups
5 91A, 91B, 91C, 91D are disposed at substantially equal
distances from the optical axis in Fig. 35. Each of
the fly eye lens groups 91A, 91B, 91C, 91D is, as
illustrated in Fig. 35, composed of, though not limited
to this, 32 pieces of lens elements. In an extreme
10 case, the fly eye lens group may be constructed of
one lens element. Now, turning to Figs. 35 and 36,
the fly eye lens groups 91A, 91B, 91C, 91D are held
by jigs 103a, 103b, 103c, 103d. These jigs 103a, 103b,
103c, 103d are further supported on movable members
15 101a, 101b, 101c, 101d through support bars 100a, 100b,
100c, 100d. These support bars 100a, 100b, 100c, 100d
are stretchable and contractible in the optical-axis
direction with the aid of drive elements such as motors
and gears incorporated into the movable members 101a,
20 101b, 101c, 101d. The movable members 101a, 101b,
101c, 101d themselves are movable along fixed guides
102a, 102b, 102c, 102d. The individual fly eye lens
groups 91A, 91B, 91C, 91D are therefore independently
movable in the intra-surface direction perpendicular
25 to the optical axis.

Respective positions (within the surface vertical
to the optical axis) of the fly eye lens groups 91A,

1 91B, 91C, 91D depicted in Fig. 36 are determined
(changed) preferably depending on the reticle patterns
to be transferred.

The optimum positions of the respective fly
5 eye lens groups are set under the same conditions as
those explained referring to Figs. 14 and 15 in the
first embodiment.

A concrete example of the positional determina-
tion of each of the fly eye lens groups is the same
10 as the determining method explained in the first
embodiment with reference to Figs. 14 and 15. It is
assumed that the central position (the optimum position
of the gravity of the light quantity distribution of
the secondary illuminant image which is created by
15 each of the fly eye lens groups) of each of the fly
eye lens groups is, as illustrated in Fig. 15B, on
the Y-directional line segment $L\alpha$ presumed within the
Fourier transform surface. Alternatively, it is assumed
that the center of each of the fly eye lens groups
20 is placed on an arbitrary position on the line segment
 $L\beta$, or, as illustrated in Fig. 15D, on the line
segments $L\alpha$, $L\beta$ defined such as $\alpha = \beta = f \cdot (1/2) \cdot$
 (λ/P_x) or on the line segments $L\gamma$, $L\epsilon$ defined such
as $\gamma = \epsilon = f \cdot (1/2) \cdot (\lambda/P_y)$. Based on these assump-
25 tions, the focal depth can be maximized. As in the
first embodiment, the 0th-order diffracted light
component D_0 coming from the reticle patterns 28 and

1 any one of the (+) primary diffracted light component
Dp and the (-) primary diffracted light component Dm
may be arranged to pass through the light paths having
the equal distances from the optical axis AX on the
5 pupil surface 51 within the projection optical system
29. If the reticle patterns 28, as seen in Fig. 15D,
contain the two-dimensional periodic patterns, and
when paying the attention to one specific 0th-order
diffracted light component, there probably exist higher-
10 order diffracted light components than the primary
light components which are distributed in the X-direction
(the first direction) and in the Y-direction (the
second direction) about the single 0th-order diffracted
light component on the pupil surface 51 of the projec-
15 tion optical system. Supposing that the image of the
two-dimensional patterns is formed well with respect
to one specific 0th-order diffracted light component,
the position of the specific 0th-order diffracted light
component may be adjusted so that three light components
20 i.e., one of the higher-order diffracted light components
distributed in the first direction, one of the higher-
order diffracted light components distributed in the
second direction and one specific 0th-order diffracted
light component are distributed at the substantially
25 equal distances from the optical axis AX on the pupil
surface 51 of the projection optical system. For
instance, the central position of the exit portion

1 in Fig. 15D is arranged to coincide with any one of
points $P\xi$, $P\eta$, $P\kappa$, $P\mu$. The points $P\xi$, $P\eta$, $P\kappa$, $P\mu$ are
all intersections of the line segment $L\alpha$ or $L\beta$ (the
optimum position to the X-directional periodicity,
5 i.e., the position in which the 0th-order diffracted
light component and one of the (\pm) primary diffracted
light components in the X-direction have the substantial-
ly equal distances from the optical axis on the pupil
surface S_1 of the projection optical system) and line
10 segments $L\gamma$, $L\epsilon$ (the optimum positions to the Y-direc-
tional periodicity). Therefore, those positions are
the light source positions optimal to either the pattern
direction X or the pattern direction Y.

Note that in this embodiment, an arbitrary
15 light quantity distribution can be, as in the first
embodiment, formed on the Fourier transform surface
by controlling the luminous flux transform member and
the movable optical member on the basis of the informa-
tion of bar codes and the like. In this case, the
20 fly eye lens groups 91A to 91D are disposed not only
discretely but also integrally about the optical axis,
whereby a changeover to the ordinary illumination can
be performed.

A light scattering member such as a diffusion
25 plate and an optical fiber bundle are provided in close
proximity to the light-source-side focal surface 91a
of the fly eye lens 91, thereby homogenizing the

1 illumination light. Alternatively, the illumination
light may be homogenized by employing an optical
integrator such as a further fly eye lens (hereinafter
referred to as the other fly eye lens) separately from
5 the fly eye lens 72 used in the embodiments of the
present invention. At this time, the other fly eye
lens is disposed preferably closer to the light source
(lamp) 1 than the optical member e.g., the diffraction
grating pattern plate 12 or 12A shown in Figs. 29 and
10 30 for making variable the illumination light quantity
distribution in the vicinity of the light-source-side
focal surface 91a of the fly eye lens 91. A sectional
configuration of each lens element of the other fly
eye lens is desirably a regular hexagon rather than
15 a square (rectangle). In this case, the σ -value may
be made variable by making the numerical aperture of
the illumination system variable while providing an
aperture stop on the reticle-side focal surface of
the other fly eye lens. Further, the σ -value may be
20 also made variable by changing a magnitude of the
luminous flux incident on the other fly eye lens while
providing a zoom lens (afocal zoom lens) on the light
path leading from the light source up to the other
fly eye lens.

25 Given above is the example of determining the
positions of the plurality of fly eye lens groups.
The illumination luminous fluxes are concentrated

1 corresponding to the moving positions of the respective
fly eye lens groups by means of the foregoing optical
members (the diffraction grating pattern plate, the
movable mirror, the prism or the fibers). The optical
5 member for this concentrating process may not be
provided.

The luminous fluxes emitted from the fly eye
lens groups are incident obliquely on the reticle.
If a direction of the light quantity gravity of the
10 (plural) incident luminous fluxes inclined thereto
is not perpendicular to the reticle, there arises a
problem in which a position of the transferred image
shifts in the intra-surface direction of the wafer
during minute defocusing of the wafer 30. In order
15 to prevent this shift, the direction of the light
quantity gravity of the (plural) illumination luminous
fluxes from the fly eye lens groups is kept vertical
to the reticle patterns, viz., parallel to the optical
axis AX.

20 More specifically, on the assumption that the
optical axis (central line) is set in the respective
fly eye lens groups, it may be sufficient to make zero
a vector sum of a product of the intra Fourier transform
surface positional vector of the optical axis (central
25 line) on the basis of the optical axis AX of the projec-
tion optical system 29 and a quantity of light emitted
from each of the fly eye lens groups. An easier method

1 is that $2m$ -groups (m is the natural number) of fly
eye lenses are provided; positions of m -groups of the
fly eye lenses are determined by the optimizing method
described above; and remaining m -groups and the former
5 m -groups of fly eye lenses are disposed in symmetry
with respect to the optical axis AX.

If the device further includes n -groups (n
is the natural number), and when the number of groups
of the fly eye lenses is set to m smaller than n , the
10 remaining $(n - m)$ groups of fly eye lenses may not
be used. To eliminate the use of the $(n - m)$ groups
of fly eye lenses, the spatial filters 210 or 16 may
be provided on the positions of $(n - m)$ groups of fly
eye lenses. At this time, the optical member for
15 concentrating the illumination light on the positions
of $(n - m)$ groups of fly eye lenses preferably does
not concentrate the light on the $(n - m)$ groups of
fly eye lenses.

The positions of openings of the spatial filter
20 210 or 16 are desirably variable corresponding to the
movements of the fly eye lens groups. Alternatively,
there is provided a mechanism for exchanging the spatial
filters 210, 16 in accordance with the positions of
the respective fly eye lenses. The device may
25 incorporate some kinds of light shielding members.

As depicted in Fig. 36, each of the jigs 103a,
103b, 103c, 103d for holding the respective fly eye

1 lens groups 91A, 91B, 91C, 91D has light shielding
blades 104a, 104b. In this case, the opening of the
spatial filter 16 may be formed considerably larger
than the diameter of the fly eye lens. Hence, one
5 spatial filter 16 is capable of corresponding to the
positions of a variety of fly eye lenses. If the light
shielding blades 194a, 194b deviate slightly in the
optical-axis direction, a constraint given to the moving
range of the fly eye lens groups is reduced.

10 Light scattering members such as diffusion
plates and optical fibers are employed in the vicinity
of the light-source-side focal surfaces 91a of the
fly eye lens groups 91A, 91B, 91C, 91D, thereby homo-
genizing the illumination light.

15 A fifth embodiment will be next explained.
Provided in this embodiment is a holding member for
integrally holding the plurality of fly eye lens groups.
The fly eye lens groups held in the optimum placement
are selectable by driving the holding member.

20 Fig. 37 illustrates a construction of the
projection type exposure apparatus in the fifth
embodiment of the present invention. The diffraction
grating pattern plate 12 is given as an optical member
(a part of the input optical system) for concentrating
25 the light quantity distributions of the illumination
light on the light-source-side focal surfaces of the
fly eye lens groups. Note that the same members as

1 those in Fig. 29 are marked with the like symbols.

A holding member 111 integrally holds fly eye lens groups 111A, 111B so that the center (in other words, the gravity of the each of the light quantity distributions created by the secondary illuminant images in the respective fly eye lens groups 111A, 111B) of each of the fly eye lens groups 111A, 111B is set in a discrete position eccentric from the optical axis AX by a quantity determined depending on the periodicity of the reticle patterns. Fixed integrally to a movable member 112 (switching member in this invention) together with the holding member 111 are a plurality of holding member (not illustrated) for holding the plurality of fly eye lens groups while making their eccentric states relative to the optical axis AX different from each other in accordance with a difference in terms of the periodicity of the reticle patterns 28. This movable member 112 is driven, with the result that the plurality of holding members can be so disposed in the light path of the illumination optical system as to be individually exchangeable. The detailed description thereof will be given later.

Each of the plurality of fly eye lens groups (111A, 111B) fixed by the same holding member desirably assumes the same configuration and is composed of the same material (refractive index). In this embodiment, the holding members (fly eye lens groups 111A, 111B)

1 are exchangeable, and hence the openings of the spatial
filter 16 have to be variable correspondingly; or
alternatively, the spatial filter 16 has to be also
exchangeable. For instance, the spatial filter 16
5 is fixed to the holding member together with the fly
eye lens groups 111A, 111B, and desirably they are
arranged to be integrally exchangeable. Note that
a magnitude (thickness) of the luminous flux incident
on each of the fly eye lens groups 111A, 111B is set
10 equal to or smaller than a magnitude of each of the
light-source-side focal surfaces 111a of the fly eye
lens groups 111A, 111B. In this case, the spatial
filter 16 is not particularly, as a matter of course,
provided in the illumination optical system (in the
15 vicinity of the fly eye lens groups).

The diffraction grating pattern plate 5 or
5A may be rotatable in an arbitrary direction within
the surface vertical to the optical axis AX. With
this arrangement, it is possible to correspond to such
20 a case that the pitch direction of the line-and-space
patterns of the reticle patterns 28 is different from
the directions X, Y (i.e., the fly eye lens groups
111A, 111B move in the pitch direction (rotate about
the optical axis AX)).

25 Provided according to this embodiment, as in
the fourth embodiment, the main control system 58 for
generalizing and controlling the device, the bar code

1 reader 61, the keyboard 63 and the drive system (motor,
gear train, etc.) 92 of movable members for moving
the fly eye lens groups 111A, 111B. Registered
beforehand in the main control system 58 are names
5 of a plurality of reticles dealt with by the stepper
and stepper operating parameters corresponding to the
names. Then, the main control system 58 outputs, when
the bar code reader 61 reads the reticle bar codes
BC, a predetermined drive command to the drive system
10 113 by selecting one of the plurality of holding members
which matches best with the previously registered
information (corresponding to the periodicity of the
reticle patterns) on the positions (within the pupil
conjugate surface) of the fly eye lens groups 111A,
15 111B as one of the operating parameters corresponding
to the names thereof. The fly eye lens groups 111A,
111B held by the previously selected holding member
are thereby set in the positions shown in Figs. 14
and 15 in the first embodiment. The operations described
20 above are executable even by the operator's inputting
the commands and the data from the keyboard 63 directly
to the main control system 58.

The optical member (input optical system) is
not limited to the transmissive diffraction grating
25 pattern plate 12, this optical member being intended
to concentrate the light quantity distributions over
the light-source-side focal surface of the

1 lens groups in the vicinity of the positions of the
individual fly eye lenses. As explained in the fourth
embodiment with reference to Figs. 30 - 34, the
reflective diffraction grating pattern plate 12A, the
5 movable plane mirror 54, the optical fibers 35, the
prism 33 and the plurality of reflection mirrors 34
may be provided in place of the diffraction grating
pattern plate 12. Additionally, the diffraction grating
pattern plates 12, 12A and the prism 33 are replaced;
10 or a plurality of angular position coordinates of the
movable plane mirror 54 are changed; or the exit
portions of the optical fibers are made movable; or
each of the reflection mirrors is provided with the
position adjusting mechanism and the mechanism for
15 adjusting the angle of rotation about the optical axis
AX. With these arrangements, if the fly eye lens groups
move with the replacement of the holding member, the
illumination luminous fluxes can be concentrated in
the vicinity of the positions of the respective fly
20 eye lens groups after being moved.

As in the fourth embodiment, the spatial filter
16 may be replaced with the spatial filter 10 shown
in Fig. 12 or used in combination with the above-
mentioned input optical system. The placement of the
25 spatial filters 10, 16 is not limited to the light-
source-side focal surfaces 111a and the reticle-side
focal surfaces 111a of the fly eye lens groups but

1 may be disposed in arbitrary positions. Further, the
optical member (input optical system) for concentrating
the illumination light only in the vicinity of the
individual fly eye lens groups 111A, 111B may be only
5 a lens having a large diameter enough to make the
illumination light incident in flood on each of the
plurality of fly eye lens groups.

As explained in the fourth embodiment in
conjunction with Fig. 26, the spatial filter 16A and
10 the field stop may be provided.

Next, a construction of the movable member
112 (switching member in the present invention) for
exchanging the holding member will be described refer-
ring to Figs. 38 and 39.

15 Fig. 38 shows a concrete construction of the
movable member. Four pieces of holding members 111,
114, 115, 116 are herein disposed at intervals of
approximately 90 degrees on the movable member (turret
plate) 112 rotatable about a rotary axis 112a. Fig.
20 38 illustrates a situation in which illumination luminous
fluxes 11a, 11b (dotted lines) are incident on the
respective fly eye lens groups 111A, 111B; and the
holding member 111 is disposed in the illumination
optical system. At this time, the holding member 111
25 is placed in the illumination optical system so that
the center of this member coincides substantially with
the optical axis AX. The plurality of fly eye lens

1 groups 111A, 111B are held integrally by the holding
member 111 so that the centers of these lens groups
are set in discrete positions eccentric from the optical
axis AX of the illumination optical system by a quantity
5 determined depending on the periodicity of the reticle
patterns. These lens groups are placed substantially
in symmetry with respect to the center (optical axis
AX) of the holding member 111.

Now, each of the four holding members 111,
10 114, 115, 116 holds the plurality of fly eye lens groups
while making their eccentric states (i.e., positions
within the surface substantially perpendicular to the
optical axis AX) from the optical axis AX (center of
the holding member) different from each other in
15 accordance with a difference in terms of the periodicity
of the reticle patterns 28. Both of the holding members
111, 114 have two fly eye lens groups (111A, 111B)
and (114A, 114B). These fly eye lens groups are, when
being disposed in the illumination optical system,
20 fixed so that their array directions are substantially
orthogonal to each other. The holding member 115 places
and fixes the four fly eye lens groups 115A - 115D
substantially at equal distances from the center 115cA
(optical axis AX) thereof. In accordance with this
25 embodiment, the holding member 116, which fixes one
fly eye lens group 116A substantially at the center,
is used for effecting the exposure based on a known
method.

1 As is obvious from Fig. 38, the turret plate
112 is rotated by the drive element 117 consisting
of a motor and a gear, as stated earlier, in accordance
with the information of the reticle bar codes BC. The
5 four holding members 111, 114, 115, 116 are thereby
exchanged, and the desired holding member corresponding
to the periodicity (pitch, array direction, etc.) of
the reticle patterns can be disposed in the illumination
optical system.

10 Selected, as discussed above, in accordance
with the information of the reticle bar codes BC is
whether to effect either the known exposure for forming
the light quantity distributions substantially about
the optical axis on the Fourier transform surface or
15 the exposure by the inclined illumination light explained
in this embodiment. In the case of performing the
known exposure, the holding member 116 is selected.
In the case of performing the exposure based on the
inclined illumination light, any one of the holding
20 members 111, 114, 115 may be selected. When executing
the known exposure, and if the holding member 116 is
selected, it is required that the input optical system
be exchanged for effecting the illumination as it used
to be done. If the illumination light can be concen-
25 trated through the lens 71 on the fly eye lens group
116A, the input optical system such as fibers, it may
be sufficient, retreat from within the light path.

1 In each of the four holding members, the
plurality of fly eye lens groups are herein fixed in
a predetermined positional relation, and hence there
is no necessity for performing the positional adjustment
5 between the plurality of fly eye lens groups when
exchanging the holding member. Therefore, positioning
of the holding members as a whole may be effected with
respect to the optical axis AX of the illumination
optical system. Consequently, there is produced such
10 an advantage that no precise positioning mechanism
is needed. At this time, the drive element 113 is
used for the positioning process, and it is therefore
desirable to provide a rotary angle measuring member
such as, e.g., a rotary encoder. Note that each of
15 the plurality of fly eye lens groups constituting the
holding members comprises, as shown in Fig. 38, 16
pieces of lens elements (only the fly eye lens group
116A is composed of 36 pieces lens elements). The
numerical number is not limited to this. In an extreme
20 case, the fly eye lens group consisting of one lens
element may also be available.

Referring to Fig. 37, the spatial filter 16
is disposed in rear (reticle-side) of the holding member
111. In each of the holding members, when the portions
25 other than the fly eye lens groups are formed as light
shielding portions, the spatial filter 16 is not
particularly provided. At this time, the turret plate

1 112 may be a transmissive portion or a light shielding
portion. The number of the holding members to be fixed
to the turret plate 112 and the eccentric states
(positions) of the plurality of fly eye lens groups
5 are not limited to those shown in Fig. 38 but may be
arbitrarily set corresponding to the periodicity of
the reticle patterns to be transferred. If there is
a necessity for strictly setting the incident angles
and the like of the illumination luminous fluxes on
10 the reticle patterns, each of the plurality of fly
eye lens groups may be so constructed as to be minutely
movable in the radial directions (radiant directions)
about the optical axis AX in the holding member. Further,
the holding members (fly eye lens groups 111A, 111B)
15 may be so constructed as to be rotatable about the
optical axis AX. On this occasion, if especially the
optical fiber bundle 35 is employed as an optical member
(input optical system) for concentrating the illumination
luminous fluxes in the vicinity of each of the plurality
20 of fly eye lens groups, the exit ends 35A, 35B thereof
are arranged to move with movements of the fly eye
lens groups. For instance, the exit ends 35A, 35B
and the fly eye lens groups may be integrally fixed.
In addition, the rectangular fly eye lens groups are
25 relatively inclined with rotation of the holding member.
However, when rotating the holding member, it is desir-
able that only the positions of the fly eye lens groups

1 are moved without causing the above-mentioned
inclination.

When exchanging the holding member, it is
necessary to exchange the input optical system such
5 as, e.g., the diffraction grating pattern plate 12,
the relay lens 73 (Fig. 37) and the optical fiber bundle
35. Desirably, the input optical systems corresponding
to the eccentric states of the plurality of fly eye
lens groups are integrally constructed for every holding
10 member and fixed to the movable member 112.

Fig. 39 is a diagram showing a variant form
of the movable member for exchanging the holding member.
The input optical system (optical fiber bundles 117,
118) and the holding members (12, 124) are integrally
15 fixed to the movable member (support bar 125). It
is permitted that the above-described other optical
systems, though the optical fiber bundle is exemplified
herein, may be employed as an input optical system.
Incidentally, the fundamental construction (the example
20 where the optical fiber bundle is used as an input
optical system) has been already explained in the fourth
embodiment (Fig. 32) and therefore touched briefly
herein.

Referring to Fig. 39, the two fly eye lens
25 groups 119A, 119B are integrally held by the holding
member 122, while an incident portion 117a and an exit
portion 117b of the optical fiber bundle 117 are both

1 held by a fixing tool 123. At the same moment, the
holding member 122 is integrally fixed to the fixing
tool 123. Excepting the fly eye lens groups 119A,
119B, the light shielding portions (the illustrated
5 oblique line portions corresponding to, e.g., the spatial
filter 16 of Fig. 37) occupy the interior of the holding
member. On the other hand, the fly eye lens groups
121A, 121B for the replacement are integrally held
by the holding member 124. An incident portion 118a
10 and an exit portion 118b of an optical fiber bundle
118 are both held by a fixing tool 125. Simultaneously,
the holding member 124 is integrally fixed to the fixing
tool 125. As in the same way described above, the
interior of the holding member 124 is formed with the
15 light shielding portions. Further, the fixing tools
123, 125 are connectively fixed by means of a connecting
member 127. Therefore, the holding members may be
exchanged for every fixing tool. Note that in Fig.
39, the fixing tool 123 (holding member 122) exists
20 in the illumination optical system, whereas the fixing
tool 125 for the replacement is set in a position
deviating from the illumination optical system. The
constructions toward the light source from the relay
lens system 71 and toward the reticle from the condenser
25 lens 74 are the same as those shown in Fig. 37.

By the way, the holding member is exchanged
by pushing or pulling the support bar 129 with the

1 help of the drive element 128. Hence, as illustrated
in Fig. 39, when exchanging the holding member, the
fly eye lens groups and the optical fiber bundle are
so arranged as to be integrally exchangeable. With
5 this arrangement, it may be sufficient that the fore-
going integral member groups (fixing tools) are matched
in position with the illumination optical system as
a whole. Produced is an advantage of eliminating the
necessity for effecting the positional adjustments
10 between the respective members (fly eye lens groups,
optical fiber bundle, etc.) per exchanging process.
At this time, the drive element 128 is employed also
for positioning. It is therefore desirable to provide
a position measuring member such as, for example, a
15 linear encoder, a potentiometer, etc..

Note that the number of the fly eye lens groups
per holding member shown in Figs. 38 and 39 and the
number of the lens elements constituting the fly eye
lens groups may be arbitrarily set. Besides, the
20 configurations of the fly eye lens group and of the
incident or exit surface of the lens element are not
limited to the rectangle.

Now, the respective positions of the plurality
of fly eye lens groups depicted in Figs. 38 and 39
25 in other words, the holding member to be selected are
preferably determined (changed) depending on the reticle
patterns to be transferred. A method of determining

1 (selecting) the positions of the respective fly eye
lens groups is the same with the fourth embodiment
(the method being identical with that explained in
the first embodiment). To be more specific, the holding
5 member including the fly eye lens group may be disposed
in the incident position (incident angle) or in the
vicinity thereof on the reticle patterns to obtain
the effects given by the improved optimum resolving
power and focal depth to the degree of fineness (pitch)
10 of the patterns to be transferred using the illumination
luminous fluxes coming from the respective fly eye
lens groups.

It is to be noted that the openings of the
spatial filter 210 or 16 are desirably variable cor-
15 responding to the movements of the respective fly eye
lens groups with the exchange of the holding member.
Provided alternatively is a mechanism for exchanging
the spatial filters 210, 12 in accordance with the
positions of the individual fly eye lenses. Besides,
20 the device may incorporate some kinds of light shielding
members.

In the embodiment discussed above, the premise
is that the plurality of holding members (fly eye lens
groups) are so constructed as to be exchangeable.
25 According to the present invention, as a matter of
course, the holding members are not necessarily so
constructed as to be exchangeable. For instance, only

1 the holding member 111 depicted in Fig. 38 is merely
disposed in the illumination optical system. With
this arrangement, there can be of course attained the
effects (to actualize the projection type exposure
5 apparatus exhibiting the high resolving power and large
focal depth) of the present invention. Incidentally,
if it is permitted to cause somewhat a loss in the
illumination light quantity from the light source,
the optical member (input optical system) for concern-
10 ing the illumination luminous fluxes on the fly eye
lens groups is not particularly disposed.

In this embodiment also, the other fly eye
lens may be also provided. The σ -value determined
by one if the respective fly eye lens groups is set
15 to preferably 0.1 through 0.3.

The cumulative focal point exposure method
described in the third embodiment is, though the first
to fifth embodiments have been described so far,
applicable to the first, second, fourth and fifth
20 embodiments.

In the first through fifth embodiments discussed
above, the explanations have been given by use of the
mercury lamp 1 as a light source. The light source
may include, however, other bright-line lamps and lasers
25 (excimers, etc.); or a continuous spectrum light source
is also available. A large proportion of the optical
members in the illumination optical system are composed

1 of the lenses. However, the mirrors (concave and convex
mirrors) are also available. The projection optical
system may come under a refractive system or reflective
system or reflective/refractive system. In the embodi-
5 ments, the double-side telecentric system is used.
However, a one-side telecentric system or non-telecentric
system is also available. If the correction of the
chromatic aberration of each optical system is insuf-
ficient, a band-pass filter and a dichroic mirror
10 intervene in the light path of the illumination system
to utilize only the monochromatic light.

Although the illustrative embodiment of the
present invention have been described in detail with
reference to the accompanying drawings, it is to be
15 understood that the present invention is not limited
to those embodiments. Various changes or modifications
may be effected therein by one skilled in the art without
departing from the scope or spirit of the invention.

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